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Remedial Action Plan and Final Design for Stabilization of the Inactive Uranium Mill Tailings At Green River, Utah

Final

Volume I - Text, Appendices A, B, and C

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Uranium Mill Tailings Remedial Action Project UMTRAP

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URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT OFFICE

ALBUQUERQUE OPERATIONS OFFICE

DEPARTMENT OF ENERGY

ALBUQUERQUE, NEW MEXICO

REMEDIAL ACTION PLAN FOR STABILIZATION OF THE INACTIVE URANIUM MILL TAILINGS SITE AT GREEN RIVER, UTAH

Approved by

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UMTRA Project
U.S. Department of Energy

EXECUTIVE SUMMARY

REMEDIAL ACTION PLAN
GREEN RIVER, UTAH, SITE

Background

The Green River inactive uranium mill site is in Grand County, Utah, approximately one mile southeast of the city of Green River, 0.5 mile south of U.S. Highway 6&50, and 0.5 mile north of Interstate 70. The 48-acre designated site consists of the eight-acre tailings pile, the mill yard and ore storage area (23 acres), four main buildings, a water tower, and several small buildings (see Figure 3.1). The buildings are all structurally sound and are slightly contaminated, except for the more-contaminated roaster building. The excavated quantities of tailings and contaminated materials consist of approximately 204,249 cubic yards of tailings, 138,217 cubic yards of other contaminated material (including windblown contaminated soil), and 39,295 cubic yards of vicinity property contaminated material. The additional contaminated material is mostly windblown contaminated soil with a smaller amount of vicinity property material found after site and vicinity property remedial action had commenced.

Remedial Action

The remedial action will consist of the cleanup, consolidation, and stabilization of all residual radioactive materials in a subsurface disposal cell located out of the floodplain of Brown's Wash and approximately 500 feet south of the existing tailings pile. A cover including a soil infiltration/radon barrier and rock layer for protection from erosion will be placed on top of the tailings. After completion of the remedial action, the U.S. Department of Energy (DOE) will retain the U.S. Nuclear Regulatory Commission (NRC) license and perform surveillance and maintenance at the final restricted site of 22 acres.

Pursuant to the requirements of the Uranium Mill Tailings Radiation Control Act (UMTRCA), the proposed remedial action plan will satisfy the U.S. Environmental Protection Agency (EPA) standards (40 CFR 192) for cleanup, stabilization, and control of the residual radioactive materials (hereafter referred to as tailings) at the Green River site. The requirement for control of the tailings (Subpart A) will be satisfied by the construction of an engineered disposal cell. Compliance with the groundwater requirements of 40 CFR 192 Subpart A will be through meeting maximum concentration limits (MCLs) or background concentration limits (see Section E.3.1). The bottom of the cell will be approximately 40 feet below the original grade. This cell will be covered with a three-foot-thick, fine-grained, sodium bentonite amended soil to form a low-permeability layer that will reduce radon release to well below the standard of 20 picocuries per square meter per second. The infiltration/radon barrier will also limit infiltration through the tailings. The saturated hydraulic conductivity of the infiltration/radon barrier will be approximately 2×10^{-8} centimeters per second. (See Sections E.1.1 and E.3.2.) A coarse-grained, six-inch-thick filter layer will be placed above the infiltration/radon layer at a slope of 20 percent to encourage runoff of precipitation. In addition, a six-foot-thick layer of select soil fill will be placed in the bottom of the disposal cell to retard the migration of any tailings contamination downward to the water table. The combination of these design features will enable the soil layers of the disposal cell to operate together at a net infiltration rate of below 2×10^{-8} cm^3/cm^2s (see Section E.3.2).

With the exception of the relic groundwater plume, the standards for cleanup of the site under Subpart B of 40 CFR 192 will be satisfied with the proposed remedial action plan. Cleanup of the tailings pile, ore storage area, vicinity properties, and windblown tailings materials will be accomplished by consolidating the materials into the disposal cell. The DOE will verify that cleanup to standards has been accomplished. Cleanup of the relic groundwater plume will be addressed in a separate process after the proposed EPA groundwater standards have been finalized.

Groundwater monitoring

A groundwater performance monitoring program will be fully developed and discussed in the Green River Surveillance and Maintenance Plan. The monitoring program will include disposal cell moisture monitoring and a network of monitor wells in the saturated bedrock surrounding the disposal cell. Monitoring in the disposal cell will consist of neutron access holes into the infiltration/radon barrier and tailings to determine changes in moisture content. This will constitute an early detection monitoring mechanism for the site. Background monitor wells and monitor wells at the point of compliance will be sampled to compare changes in groundwater quality. Further explanation of the monitoring program is found in Section E.3.4.

Design changes

Changes in the disposal cell design since release of the January 1989 Remedial Action Plan (RAP) have been proposed for two reasons. First, the NRC requested changes in the design specifications (i.e., six percent bentonite added to the infiltration/radon barrier soils). Second, the topslopes of the disposal cell were changed from five percent to 20 percent to accommodate additional quantities of contaminated materials. A justification of the disposal cell design and responses to the NRC comments and agreement issues have been added in this Executive Summary and in Section 4.0.

Major design changes from the February 1988 RAP that are included in this RAP are:

1. An increase in the thickness of the sodium bentonite amended infiltration/radon barrier from 12 inches to 36 inches. (The DOE proposed increasing the thickness from 12 to 18 inches in a letter to the NRC dated August 19, 1988.)

2. The elimination of the select fill layer for frost protection. However, the thicker infiltration/radon barrier will still result in a 15-inch thickness of infiltration/radon barrier below the calculated maximum frost depth of 39 inches.

3. The placement of a six-foot-thick select fill soil layer beneath the tailings on top of the exposed bedrock at the bottom of the cell. This layer will increase the leachate travel time from the tailings to the point of compliance (POC).

4. A revision of the disposal cell toe to increase contaminated material capacity and slightly reduce the amount of type B riprap needed to protect against erosion.

5. The deeper excavation of the disposal cell by 17 feet to provide capacity for additional contaminated materials and the select fill soil layer. By deepening the cell rather than expanding horizontally, the design still minimizes the surface area upon which precipitation will fall and infiltrate into the cell.

6. The infiltration/radon barrier will be amended with six percent sodium bentonite instead of three percent. A requirement was added that the first lift of the infiltration/radon barrier must have 70 percent of the material passing the No. 200 sieve and the remaining infiltration/radon barrier must have 50 percent of the material passing the No. 200 sieve. These requirements were added at the request of the NRC to increase the reasonable assurance that the performance cell would comply with the proposed EPA groundwater protection standards.

Revised specifications and drawings are presented in Appendix F. New calculations and data are in the accompanying calculation volumes.

Technical Evaluation Report open issues

The current status of the thirteen open issues defined in the April 20, 1988, Technical Evaluation Report (TER) is summarized below.

Issue	Resolution
1. The U.S. Department of Energy (DOE) has not submitted all the test data for the amended soil used in the infiltration/radon barrier and demonstration of achieving the hydraulic conductivity assumed in the design . . .	The infiltration/radon barrier thickness has been increased from one foot to three feet (see Section 4.0). The DOE has demonstrated at the Tuba City, Arizona, site that infiltration/radon barriers with a saturated hydraulic conductivity of 1.3×10^{-8} centimeters per second (cm/s) can be constructed. The saturated hydraulic conductivity of the Green River infiltration/radon barrier will be approximately 2×10^{-8} cm/s. Laboratory testing data are contained in Appendix D.4, Volume IIA of the RAP dated January 1988 and in the calculation volumes accompanying this RAP.

Issue	Resolution
2. The DOE has not established the geochemical conditions . . .	The DOE proposes to meet maximum concentration limits (MCLs) or background levels at the POC without taking credit for natural geochemical attenuation. See Section E.3.3.
3. The DOE has not determined whether a tailings amendment is necessary . . .	A tailings amendment for geochemical attenuation is not needed to meet MCLs or background levels at the POC. The DOE considers geochemical amendments to be research-level concepts that are not currently appropriate for use at Green River. See Section E.3.3.
4. The DOE has not determined whether a geochemical liner is necessary . . .	A geochemical liner is not needed to meet MCLs or background levels at the POC. However, a six-foot-thick layer of select soil fill will be placed at the bottom of the disposal cell to extend leachate travel time before reaching the POC. The select fill or buffer layer will also have the capacity to retain construction water in interstitial pore spaces. This six-foot- thick buffer layer has an unquantified capacity to neutralize acidic tailings fluids; however, this has not been considered in the overall performance of the disposal cell. See Sections E.2.1.2 and E.3.2.
5. The DOE has not determined the source of the organics in the leachate . . .	The source of detectable methylene chloride was determined to be from analytical laboratory procedures. Reanalysis of water samples from selected monitor wells at the processing site have shown that no other organic compounds are present in confirmable concentrations. See Section D.5.2.7 and accompanying calculation volumes.
6. The DOE has not specified or proposed concentration limits for all constituents found in groundwater and the tailings under Subpart A . . .	Proposed concentration limits for all listed constituents are listed in Section E.3.1.2.
7. The DOE has not specified a POC . . .	The POC is described in Section E.3.1.3 and is shown in Figures E.3.1 and E.3.2.

Issue	Resolution
8. The DOE has not estimated potential downgradient concentrations for all listed constituents . . .	Estimated potential downgradient concentrations for all listed constituents are not given because the DOE intends to meet MCLs or background concentrations at the POC for the identified hazardous constituents.
9. The DOE has not proposed a groundwater performance monitoring program . . .	The groundwater performance monitoring program is discussed in Section E.3.4.
10. The DOE has not proposed a corrective action plan . . .	The corrective action plan is described in Section E.3.5.
11. The DOE has not specified or proposed concentration limits for all constituents found in groundwater and in the tailings under Subpart B . . .	The DOE plans to address this issue fully after the proposed EPA groundwater standards have been finalized.
12. The DOE has not included a restoration plan to clean up relic groundwater contamination . . .	The DOE plans to address this issue fully after the proposed EPA groundwater standards have been finalized. See Section E.3.6.
13. The DOE has not proposed a groundwater monitoring program to verify plume movements . . .	The DOE will monitor groundwater conditions at the disposal site and at the tailings pile during tailings stabilization and as part of surveillance and maintenance following stabilization of the tailings. See Section E.3.4 for further information.

<u>April 1989 Agreement Issues</u>

Issue	Resolution
1. The DOE commits to provide an adequate written justification that the design of the disposal unit represents the best design to comply with the proposed EPA groundwater protection standards.	A justification of the design was provided to the NRC in May 1989 and a revised justification was provided in August 1989. The latest version of the design justification is included in this RAP in Section 4.3.5.
2. The DOE commits to assessing whether the contaminated windblown and vicinity property materials are significant sources of hazardous constituents.	Samples of contaminated windblown and vicinity property material were subjected to batch leaching and column leaching. A layer of buffer soil was also included in the lower part of the

Issue	Resolution
	leaching columns. Based on the leaching test results, the DOE believes the windblown and vicinity property materials are clean and can be considered to have properties similar to the buffer material placed at the bottom of the cell. Further explanation is provided in Section D.5.2.8 of the RAP.
3. The DOE commits to perform moisture content and hydraulic conductivity testing of the radon barrier to ensure that the as-built saturated hydraulic conductivity does not exceed 2 X 10^{-8} cm/s. The testing should have a frequency of at least one test per 2000 cubic yards of infiltration/radon barrier material.	The testing was agreed to by the DOE and the tests were performed. Results of the tests are provided in the accompanying calculation volumes. The saturated hydraulic conductivity of the radon barrier was found to be lower than 2 X 10^{-8} cm/s.
4. The DOE commits to placing and maintaining contaminated materials in the disposal cell that are less than their average steady state moisture contents and, in any case, less than five percent by volume for tailings and 10.6 percent by volume for other contaminated material.	The DOE committed to placing the material to meet the required moisture contents. However, the DOE also had to comply with requirements of the Utah Department of Health that dust be controlled during construction. Water was sparingly sprayed on construction areas to control the dust. The resulting average volumetric moisture content was 7.1 percent for tailings and 10.6 percent for other contaminated material. An evaluation of the higher moisture content in the tailings was conducted to determine if the transport time of tailings leachate would be shorter than had been predicted. The higher moisture content of the tailings was found to have an insignificant effect upon the leachate transport time. Further details of this issue are provided in Section E.3.2 of this RAP.
5. The DOE commits to mixing no less than six percent by weight of sodium bentonite into the radon barrier.	The DOE revised the specification requiring that the infiltration/radon barrier be amended with six percent (see Section 2200 of the specifications in Appendix F). Records of

	Issue	Resolution
		testing conducted during construction indicate that this requirement was met during construction.
6.	The DOE commits to constructing the first lift of the infiltration/radon barrier with material that has greater than 70 percent of the material passing the No. 200 sieve and material for the other lifts having 50 percent passing the No. 200 sieve.	The DOE required the subcontractor to comply with the additional particle size gradation requirements. Tests that were performed during construction demonstrated that the requirements were achieved.
7.	The DOE commits to evaluating whether beryllium is a hazardous constituent in the contaminated materials at the Green River site.	Laboratory tests performed on contami-contaminated materials from the Green River site revealed that beryllium is not present in the Green River disposal cell.
8.	The DOE commits to include arsenic, lead, and methylene chloride in the list of hazardous constituents.	The revised list of hazardous constituents, which includes arsenic, lead, and methylene chloride, is included in Table E.1.1 of this RAP.
9.	The DOE commits to the interim concentration limits proposed in the April 1989 agreement.	The interim concentration limits have been incorporated into Table E.1.1 of this RAP.
10.	The DOE commits to collecting and analyzing groundwater samples from monitoring wells 807, 812, 813, 818, and 823 on a quarterly basis during construction of the disposal unit. Post remedial action monitoring of the listed wells and new wells will be conducted on a quarterly basis for a period of two years following completion of construction.	The sampling during remedial action agreed to by the DOE was implemented. The sampling for the post remedial action period will be described in the Green River Surveillance and Maintenance Plan and is summarized in Section E.3.4 of this RAP.
11.	The DOE commits to a point of compliance that is as close as reasonable to the disposal unit and extends along the entire northwest and northeast edges of the disposal unit.	The agreed upon point of compliance is illustrated in Figure E.3.1 of this RAP.
12.	The DOE commits to demonstrating compliance with EPA groundwater cleanup standards of 40 CFR 192, Subparts B and C, after they have been finalized by the EPA.	Agreed.

Design options considered but rejected

Numerous options and features were evaluated for inclusion in the final design of the tailings cell but were rejected for a variety of reasons. The current design incorporates all the design innovations that are reasonable and prudent to ensure that the EPA standards will be achieved. Other concepts that have been considered (1) were found to be impractical for the Green River site; (2) are considered to be unproven technological applications; or (3) would not provide additional assurance of meeting the EPA standards.

A geochemical liner or amendment was considered, which would potentially attenuate contaminants in leachate from the tailings. Attenuation would be achieved through adsorption, absorption, or reduction reactions and could help to lower contaminant concentrations at the POC. However, these technologies have not been applied to full-scale field tests at uranium tailings piles. Thomson (1988) had determined that while batch and column tests show promising results using this concept, considerable additional testing including long-term leaching is required before it can be used with confidence. Other concerns are the possible settlement of peat amendments, and creating a bathtub effect if a lime or calcium carbonate liner clogs up. The degree of attenuation could vary widely with changes in tailings geochemistry. Due to the uncertainties inherent with geochemical modifiers, and the extended leachate travel time associated with the current design, this option was not incorporated into the cell design. The cell design will still comply with the primary EPA groundwater standards (MCLs and background concentration limits) even without a liner or amendment.

Several changes in the cover layers to further reduce infiltration were evaluated; i.e., a sodium amendment to the infiltration/radon barrier, steeper slopes, a CLAYMAX^R membrane, a soil/rock matrix layer, and a vegetated soil cover. Applying additional sodium to the infiltration/radon barrier could create a dispersed soil with a lower hydraulic conductivity. A lower cover flux rate would be beneficial to groundwater protection. However, laboratory testing resulted in only a small decrease in saturated hydraulic conductivity with large amounts of sodium bentonite (25 percent). The infiltration/radon barrier was proposed to be amended with three percent sodium bentonite. At the request of the NRC, the amount of sodium bentonite in the infiltration/radon barrier was increased to six percent. Considering the laboratory test results and that a field test of a sodium amendment for uranium tailings covers has not been conducted, it is prudent not to include an additional sodium amendment in the cover design.

Steepening the top and sideslopes of the cover would have the beneficial effect of shedding direct precipitation faster than the current design so that less net infiltration through the tailings may occur. The current design includes 5:1 (20 percent) slopes. The main drawback of steepening the slopes is that the mean diameter of the rock and possibly the rock thickness would need to be increased to compensate for faster flow velocities. Suitable quality rock for the site is being hauled from a quarry 75 miles away at great expense and relatively high transportation safety risk. Larger rock in sufficient quantities is not available from the quarry. In order to avoid the additional transportation hazards posed by using rock from an even more distant source, steepening cover slopes has not been included in the cell design.

Furthermore, the proposed design will meet the primary EPA groundwater standard without making alterations to the slopes.

Using a CLAYMAX^{R} geotextile/bentonite layer was considered because it could restrict saturated hydraulic conductivity through the cover to approximately 2 x 10^{-9} cm/s. The current infiltration barrier will have a saturated hydraulic conductivity of approximately 2 x 10^{-8} cm/s. The performance assessment in Section E.3.3 concludes that the current design would ensure that MCLs or background concentrations are achieved at the disposal cell POC for all identified hazardous constituents. Incorporating a CLAYMAX^{R} layer at the Green River site would necessitate expanding the land area occupied by the cell so that gentler slopes could be used. Sufficient land area is not available without encroaching on geomorphic features that would reduce long-term erosion protection. Considering the current design will meet the primary EPA groundwater standard, using CLAYMAX^{R} was not found to be necessary.

Alternative surface layers, such as rock with a soil matrix and a vegetated soil cover, were considered for use at the Green River site, but were rejected for the reasons explained below. A rock/soil matrix layer is less resistant to erosion than the current rock cover, assuming the slope angles remain the same. Slopes could be made less steep so that the soil/rock matrix would meet the criteria for protection from erosion. However, geomorphic features constrain the area available to expand the cell for longer slopes; i.e., setbacks required to protect the site from gully intrusion and retreat of the Brown's Wash escarpment. A vegetated cover was determined to be impractical for the Green River site because of the low annual precipitation (six inches). Even if a vegetated cover could be satisfactorily established, it probably would not persist over the 1000-year design life of the disposal cell because of the combination of low precipitation and occasional droughts. Again, because the current design can meet the proposed concentration limits, pursuing the change was not necessary.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 PURPOSE

This Remedial Action Plan (RAP) has been developed to serve a threefold purpose. It presents the series of activities that are proposed by the U.S. Department of Energy (DOE) to accomplish long-term stabilization and control of radioactive materials at the inactive uranium processing site located near Green River, Utah. It provides a characterization of the present conditions of the site. It also serves to document the concurrence of the state of Utah and the U.S. Nuclear Regulatory Commission (NRC) in the remedial action. This agreement, upon execution by the DOE and the state of Utah, and concurrence by the NRC, becomes Appendix B of the Cooperative Agreement.

1.2 RESPONSIBILITIES

In 1978, Congress passed Public Law 95-604, the Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978, expressly finding that uranium mill tailings located at inactive (and active) mill sites may pose a potential health hazard to the public. Title I to the UMTRCA identified sites to be designated for remedial action. On November 8, 1979, Green River, Utah, was designated as one of the sites.

The UMTRCA charged the U.S. Environmental Protection Agency (EPA) with the responsibility for promulgating remedial action standards for inactive mill sites. The purpose of these standards is to protect the public health and safety and the environment from radiological and nonradiological hazards associated with radioactive materials at the sites. The final standards were promulgated with an effective date of March 7, 1983.

The DOE will select and execute a plan of remedial action that will satisfy the EPA standards and other applicable laws and regulations. Under the UMTRCA, the DOE and the state of Utah entered into a cooperative agreement effective January 30, 1981, for remedial action at the Green River site. The DOE will fund 90 percent and the state of Utah will fund 10 percent of the allowable cost.

All remedial actions must be selected and performed with the concurrence of the NRC. In conformance with the UMTRCA, the required NRC concurrence with the selection and performance of proposed remedial actions and the licensing of long-term surveillance and maintenance of disposal sites will be for the purpose of ensuring compliance with the standards established by the EPA. Therefore, the RAP constitutes the initial document in the licensing process. A detailed listing of the responsibilities of the project participants is included in Section 6.0 of this report.

1.3 SCOPE AND CONTENT

This document has been structured to provide a comprehensive understanding of the remedial action proposed for the Green River site. It includes specific design requirements for the detailed design and construction of the remedial action. An extensive amount of data and supporting information have been generated for this remedial action that cannot all be incorporated into this single document. Pertinent information and data are included with reference given to the supporting documents.

Section 2.0 presents the EPA standards, including a discussion of their objectives. Section 3.0 summarizes the present site characteristics and provides a definition of site-specific problems. Section 4.0 is an overview of the proposed action and includes a justification of the design. Section 5.0 describes the water resources protection strategy with emphasis on groundwater. Section 6.0 summarizes the plan for ensuring environmental, health, and safety protection for the surrounding community and the remedial action workers. Section 7.0 presents a detailed listing of the responsibilities of the project participants. Section 8.0 describes the features of the long-term surveillance and maintenance plan. Section 9.0 presents the quality assurance aspects of the project. Section 10.0 documents the ongoing activities to keep the public informed and participating in the project.

Attached as part of the RAP are appendices that describe various aspects of the remedial action in more detail.

Appendix A, Regulatory Compliance, describes in detail the permits necessary for the remedial action activities.

Appendix B, Radon Barrier Design, describes the methodology for calculating the radon cover thickness.

Appendix C, Radiological Support Plan, describes the procedures used to characterize the present radiological condition of the site and the procedures to be used to control and verify the results of remedial action activities.

Appendix D, Site Characterization, includes all pertinent data necessary for the design of the proposed remedial action. It contains a summary of the geotechnical, hydrological, radiological, meteorological, and physical data necessary to describe the existing conditions at the Green River site.

Appendix E, Water Resources Protection Strategy, explains how the remedial action will comply with the proposed EPA groundwater protection standards.

Appendix F, Final Plans and Specifications, contains the bid schedule, special conditions, specifications, and subcontractor drawings.

Two additional volumes should be considered along with the RAP. A volume of calculations and a volume of soil testing data have been compiled for review with the RAP.

1.4 COLLATERAL DOCUMENTS

The Environmental Assessment (EA) (DOE, 1988a) describes the existing conditions at the site and the expected results of the remedial action. The EA describes the proposed remedial action and alternatives, the environmental impacts of the proposed action, and includes details that are not reported in the RAP. The final EA was published in 1988.

Additional supporting documents are the Technical Approach Document (DOE, 1988b) and a document on design criteria (DOE, 1983), which provide general guidance on the operating procedures, formats for drawings, specifications, calculations, schedules and cost estimates, and minimum design constraints to be incorporated in the final design documents. This general guidance is to be used in conjunction with the RAP as the basis or guideline for preparation of the final design documentation for Uranium Mill Tailings Remedial Action (UMTRA) Project sites. It is further intended to provide sufficient criteria for the reader to understand the constraints, procedures, codes, and standards to be used during the design and performance of the remedial actions at the UMTRA Project sites.

Copies of these documents, as well as supporting data and calculations, are on file in the UMTRA Project Office in Albuquerque, New Mexico.

2.0 EPA STANDARDS

The requirements and considerations for long-term isolation and stabilization of tailings, radon control, cleanup of land and buildings, and protection of water quality have been discussed and published in the Plan for Implementing EPA Standards for UMTRA Sites (DOE, 1984). This document was used as a guide in the development of the RAP and is the basis for the following discussion of the EPA standards.

2.1 GENERAL

Pursuant to the requirements of the UMTRCA, the EPA promulgated health and environmental standards to govern cleanup, stabilization, and control of residual radiological materials at inactive uranium mill tailings sites. The promulgated standards establish requirements for long-term stability and radiation protection and provide procedures for ensuring the protection of groundwater quality.

In developing the standards, the EPA determined "that the primary objective for control of tailings should be isolation and stabilization to prevent their misuse by man and dispersal by natural forces such as wind, rain, and flood waters" and that "a secondary objective should be to reduce radon emissions from tailings piles." A third objective should be "the elimination of significant exposure to gamma radiation from tailings piles" (ref. preamble to Standards for Remedial Actions at Inactive Uranium Processing Sites, 40 CFR 192). These conclusions were based on a determination that the most significant public health risks associated with inactive tailings were posed by exposure of people living and working in structures contaminated by tailings. The EPA further concluded that the potential for contamination of groundwater and surface water should be evaluated on a site-specific basis.

The EPA standards are discussed in the following paragraphs and are summarized in Table 2.1.

2.2 LONG-TERM STABILITY

Isolation and stabilization of tailings in order to prevent misuse by humans and dispersion by natural forces is the primary objective of the EPA standards. Accordingly, long-term stability was emphasized in the development and promulgation of the standards. This is consistent with the guidance provided by the legislative history of the UMTRCA, which stresses the importance of avoiding remedial actions that would be effective only for a short period of time and that would require future Congressional consideration.

The EPA standard-setting process distinguished "passive controls" such as thick earthen covers, below-ground disposal, rock covers, and massive earth and rock dikes, from "active controls" such as semi-permanent covers, warning signs, and restrictions on land use. Active control covers could be expected to need frequent replacement or other

PART 192 - HEALTH AND ENVIRONMENTAL PROTECTION STANDARDS FOR URANIUM MILL TAILINGS

SUBPART A - Standards for the Control of Residual Radioactive Materials from Inactive Processing Sites

192.02 Standards

Control shall be designed to:

(a) Be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years, and,

(b) Provide reasonable assurance that releases of radon-222 from residual radioactive material to the atmosphere will not:

(1) Exceed an average release rate of 20 picocuries per square meter per second, or
(2) Increase the annual average concentration of radon-222 in air at or above any location outside the disposal site by more than one-half picocurie per liter.

SUBPART B - Standards for Cleanup of Land and Buildings Contaminated with Residual Radioactive Materials from Inactive Uranium Processing Sites

192.12 Standards

Remedial actions shall be conducted so as to provide reasonable assurance that, as a result of residual radioactive materials from any designated processing site:

(a) The concentration of radium-226 in land averaged over any area of 100 square meters shall not exceed the background level by more than -

(1) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and
(2) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface.

(b) In any occupied or habitable building -

(1) The objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL. In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and
(2) The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour.

SUBPART C - Implementation (condensed)

192.20 Guidance for Implementation

Remedial action will be performed with the "concurrence of the Nuclear Regulatory Commission and the full participation of any state that pays part of the cost" and in consultation as appropriate with other government agencies.

192.21 Criteria for Applying Supplemental Standards

The implementing agencies may apply standards in lieu of the standards of Subparts A or B if certain circumstances exist, as defined in 192.21.

192.22 Supplemental Standards

"Federal agencies implementing Subparts A and B may in lieu thereof proceed pursuant to this section with respect to generic or individual situations meeting the eligibility requirements of 192.21."

(a) ". . .the implementing agencies shall select and perform remedial actions that come as close to meeting the otherwise applicable standards as is reasonable under the circumstances."

(b) ". . .remedial actions shall, in addition to satisfying the standards of Subparts A and B, reduce other residual radioactivity to levels that are as low as is reasonably achievable."

(c) "The implementing agencies may make general determinations concerning remedial actions under this Section that will apply to all locations with specified characteristics, or they may make a determination for a specific location. When remedial actions are proposed under this Section for a specific location, the Department of Energy shall inform any private owners and occupants of the affected location and solicit their comments. The Department of Energy shall provide any such comments to the other implementing agencies [and] shall also periodically inform the Environmental Protection Agency of both general and individual determinations under the provisions of this section."

Ref: Federal Register, Volume 48, No. 3, January 5, 1983, 40 CFR Part 192.

TABLE 2.1 EPA STANDARDS

major repairs requiring the appropriation and expenditure of public funds. In setting the standards, the EPA called for designs that rely primarily on passive controls.

The standard is framed as a longevity requirement that recognizes the difficulty in predicting very long-term performance with a very high degree of confidence. In establishing the longevity requirement, the EPA concluded that existing knowledge permits the design of control systems that have a good expectation of lasting at least 1000 years. Therefore, a design objective of 1000 years was established to be satisfied whenever reasonably achievable, but in any case, with a minimum performance period of 200 years.

The standard recognizes the need for institutional controls such as custodial maintenance, monitoring, and contingency response measures. In its preamble to the standards, the EPA calls for such controls to be provided as an essential backup to the primary passive controls.

2.3 RADON EMISSIONS CONTROL

The EPA identified a reduction of radon emission from tailings piles as the second objective in its standards for the control of tailings. In developing the standards, the EPA considered several alternative approaches and selected an emission limitation as the primary form of the standard. In addition, a concentration limit was established by the EPA as an alternative form of the standards for use in cases where the DOE determined that the alternative was appropriate.

In establishing the emission limitation for tailings piles, the EPA sought to reduce both the maximum risk to individuals living very near to the sites and the risk to the population as a whole. With regard to individuals very near to disposal sites, the EPA estimates that exposure to radon emissions will be reduced by more than 96 percent. The radon standard will limit the increase in radon concentration attributable to a pile to a small increase above the background radon level near the disposal site. Both radon standards are design standards with compliance to be determined on the basis of predicted rather than measured emission rates and concentrations. The EPA states that "post-remediation monitoring will not be required to show compliance, but may serve a useful role in determining whether the anticipated performance of the control system is achieved."

In establishing the radon standard, the EPA determined that the emission limitation could be achieved by well-designed thick earthen covers and that such control techniques would be compatible with the requirements of the EPA longevity standard.

2.4 WATER QUALITY PROTECTION

The EPA reviewed available water quality data at inactive tailings sites and determined that there was little evidence of recent movement of contaminants into groundwater. They also determined that any degradation of groundwater quality should be evaluated in the context of potential beneficial uses of the groundwater as determined by background water quality and the available quantity of groundwater.

Rather than establish specific numerical limitations for contaminant discharges or groundwater quality, the EPA determined that the most appropriate course of action would be to require site-specific analyses of potential future contaminant discharge and a case-by-case evaluation of the significance of such a discharge. The implementation guidelines for the EPA standards call for adequate hydrological and geochemical surveys at each site as a basis for determining whether specific water-protection measures should be applied.

Specific site assessments must include monitoring programs sufficient to establish background groundwater quality through one or more upgradient wells, and to identify the present movement and extent of contaminant plumes associated with the tailings piles. The site assessments further call for judgements of the need for restoration or prevention of contamination, or both, to be guided by the EPA's hazardous waste management system and relevant state and Federal water quality criteria. Decisions on specific actions to protect or restore water quality are to be guided by such factors as the technical feasibility of improving the aquifer, the cost of applicable restorative or protective programs, the present and future value of the aquifer as a water source, the availability of alternate water supplies, and the degree to which human exposure is likely to occur.

The UMTRCA requires that the standards promulgated by the EPA "to the maximum extent practicable, be consistent with the requirements of the Solid Waste Disposal Act, as amended." In setting the standards, the EPA determined that the statutory requirement for the NRC to concur with the selection and performance of remedial actions and to issue licenses encompassing "monitoring, maintenance, or emergency measures necessary to protect public health and safety" was consistent with the EPA regulations implementing the Solid Waste Disposal Act (47 FR 32274, July 26, 1982). Accordingly, the EPA established the implementation procedures requiring case-by-case evaluations of potential contamination at sites. Decisions regarding monitoring or remedial actions will be guided by relevant considerations in the hazardous waste management systems.

On September 3, 1985, the U.S. Tenth Circuit Court of Appeals remanded the groundwater standards (40 CFR 192.2(a)(2)-(3)). The EPA issued proposed standards for comment on September 24, 1987. Prior to promulgation of the final standards, the DOE intends to implement the provisions of Subpart A and C to the extent reasonably achievable within the UMTRA Project regulatory framework. When the final EPA standards are promulgated, the DOE will re-evaluate its groundwater protection plan and undertake such action as necessary to ensure that the revised standards are met. The need for and extent of aquifer restoration will be evaluated in a separate National Environmental Policy Act (NEPA) decision-making process.

In response to the Court's remand, the newly proposed EPA groundwater standards involve:

- o Protection of human health and safety and the environment.
- o Consideration of radiological and nonradiological hazards.
- o Consistency with the requirements of the Resource Conservation and Recovery Act (RCRA), as amended.
- o General standards applicable to all UMTRA Project sites (i.e., not site-specific as was the case for the remanded standards).

These items are discussed below.

Subpart A (40 CFR 192.01-192.02) consists of the requirements for control of potential contaminant releases to the groundwater at disposal sites. It incorporates the following:

- o RCRA list of hazardous constituents (40 CFR 264.93).
- o RCRA maximum concentration limits (MCLs) (40 CFR 264.94), background limits, or alternate concentration limits (ACLs). The establishment of ACLs must be concurred in by the NRC, be as low as reasonably achievable, and satisfy the water quality protection considerations stipulated in 40 CFR 264.94(b).
- o RCRA point of compliance (40 CFR 264.95).
- o Four hazardous constituents and their associated MCLs (molybdenum, radium, uranium, and nitrate) are added to those taken from the drinking water standards. (Note: an MCL for an additional constituent, gross alpha, is included separately and without discussion in Subpart A, Table A).
- o A liner or equivalent beneath the disposal site if tailings contain excess water (40 CFR 192.20).
- o Monitoring during a post-remedial-action period to verify design performance.
- o Corrective action to be initiated within 18 months after monitoring indicates or projects an exceedance of the applicable concentration limits.

Subpart B (40 CFR 192.11-192.12) lists the standards applicable for remediating contaminated groundwater. It incorporates:

- o Cleanup of the listed groundwater constituents to levels specified in Subpart A.
- o Extension of the remedial period to allow for natural flushing if:

- The groundwater is not, and is not projected to be, a public drinking water source, and

- Institutional controls will effectively protect health and satisfy other beneficial uses, and

- Concentration limits (40 CFR 264.94) will be met in less than 100 years.

Subpart C (40 CFR 192.20-192.22) addresses supplemental standards applicable to Subparts A and B. The supplemental standards provide for alternative actions that come as close to the standards "as reasonable under the circumstances." The NRC's concurrence in the application of supplemental standards is required. The supplemental standards may be applied if protection of human health and the environment is assured (40 CFR 192.22(d)) and:

- o The proposed action would cause more environmental harm than it would prevent (40 CFR 192.21(b)), or

- o Restoration is technically impracticable from an engineering perspective (40 CFR 192.21(f)), or

- o The groundwater is Class III (40 CFR 192.21(g)).

2.5 CLEANUP OF LANDS AND BUILDINGS

The EPA evaluated the risk associated with the dispersion of tailings off the site and concluded that the principal risk to humans was from exposure to radon daughter products inside buildings. The EPA therefore stated that the objective of the cleanup of tailings from around existing structures was to achieve an indoor radon daughter concentration (RDC) of less than 0.02 working level (WL). For open lands, the purpose of removing the contamination is to remove the potential for excessive indoor RDCs that might arise from new construction on contaminated land. The five picocuries per gram (pCi/g) and 15 pCi/g Ra-226 concentration limits for 15-centimeter surface and subsurface layers were considered adequate to limit indoor RDCs to below 0.02 WL. A secondary concern was to limit exposure of people to gamma radiation.

The standard requires that residual radioactive materials exceeding 0.03 WL be removed from buildings. In cases where levels are between 0.02 and 0.03 WL, the Federal government will have the flexibility to use measures such as sealants, filtration devices, or ventilation devices to reduce concentrations to below 0.02 WL.

3.0 SITE CHARACTERIZATION SUMMARY

This section summarizes the present conditions of the Green River site with emphasis on the radiation, geotechnical, and groundwater characteristics due to their importance in the remedial action design. The detailed characterization of the site is found in Appendix D, Site Characterization with additional data in calculation and data volumes.

3.1 SITE DESCRIPTION

3.1.1 Processing site

The Green River inactive uranium mill site is in Grand County, Utah, approximately one mile southeast of the city of Green River and 0.5 mile south of U.S. Highway 6 & 50 (U.S. 6 & 50). The 48-acresite is in Sections 15 and 22, Township 21 South, Range 16 East, Salt Lake Meridian, and is bordered by the mainline track of the Denver and Rio Grande Western (D&RGW) Railroad on the north and the recently completed Interstate 70 (I-70) on the south. The locations of the Green River tailings site, disposal area, and soil borrow site are shown in Figure 3.1.

The 48-acre designated site (Figure 3.2) consists of the tailings pile (eight acres), the mill yard and ore storage area (23 acres), four main buildings, a water tower, and several small buildings. The buildings are all structurally sound and most are slightly contaminated.

Dispersion of tailings by wind and water erosion has contaminated approximately 30 acres. The total volume of contaminated materials, including the tailings, underlying soils, windblown contaminated soils, and vicinity property materials were originally estimated to be approximately 200,000 cubic yards (cy). During construction, a total quantity of 381,761 cubic yards of tailings and contaminated material were excavated and placed in the disposal cell.

Access to the mill yard is restricted by a six-foot-high security fence with locked gates. The tailings pile is also fenced to restrict vehicle and livestock access; however, pedestrian traffic is not restricted. The remainder of the site is not fenced and access is not restricted. Radiation warning signs are posted on the fences at the site.

The surface of the tailings pile was covered with a layer of earthen material averaging six inches thick. This cover has eroded in places. Also, riprap and ditches were placed around the north and east edges of the pile to control water runoff into Brown's Wash, which parallels the site on the north.

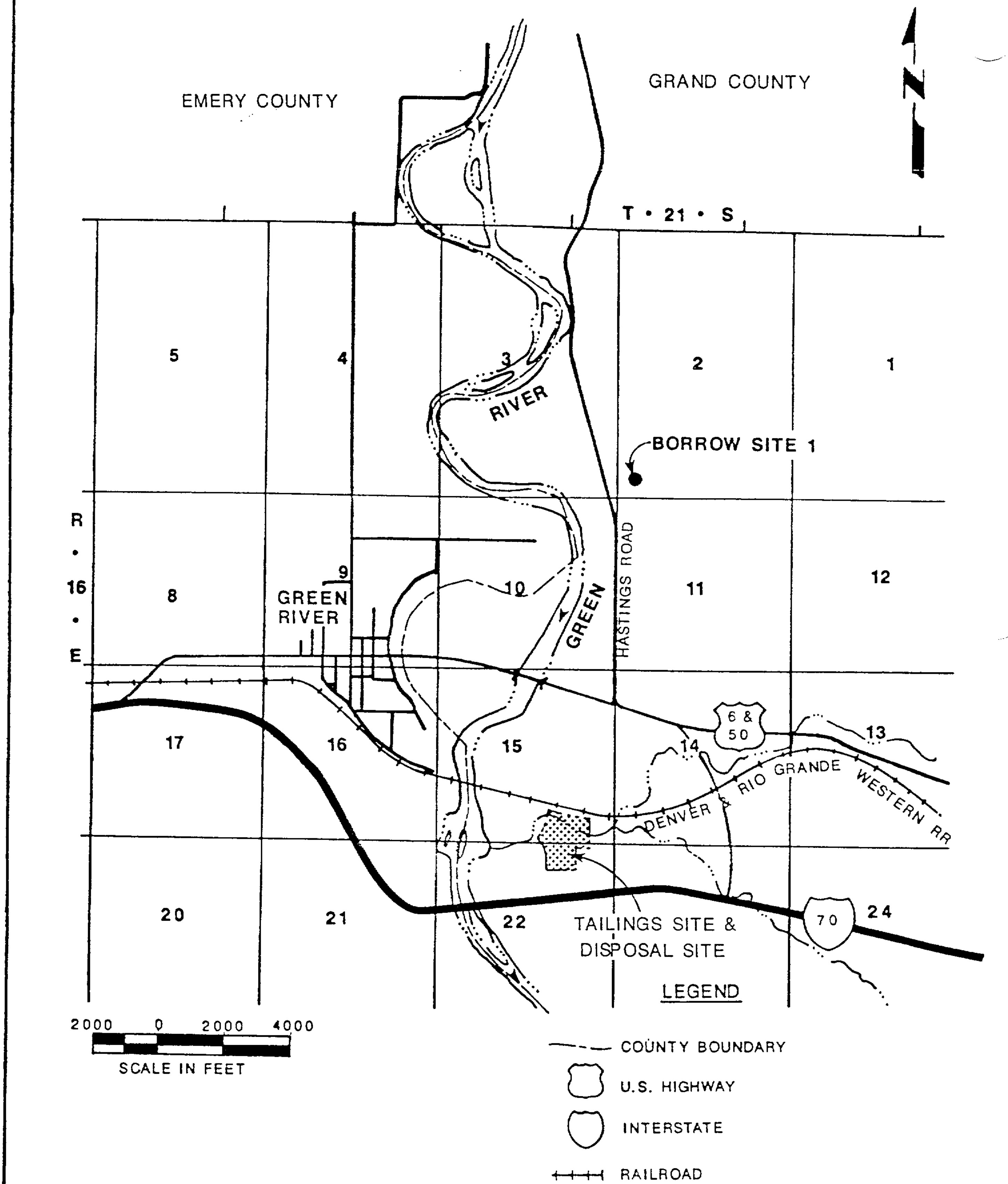


FIGURE 3.1 GREEN RIVER SITE AREA MAP

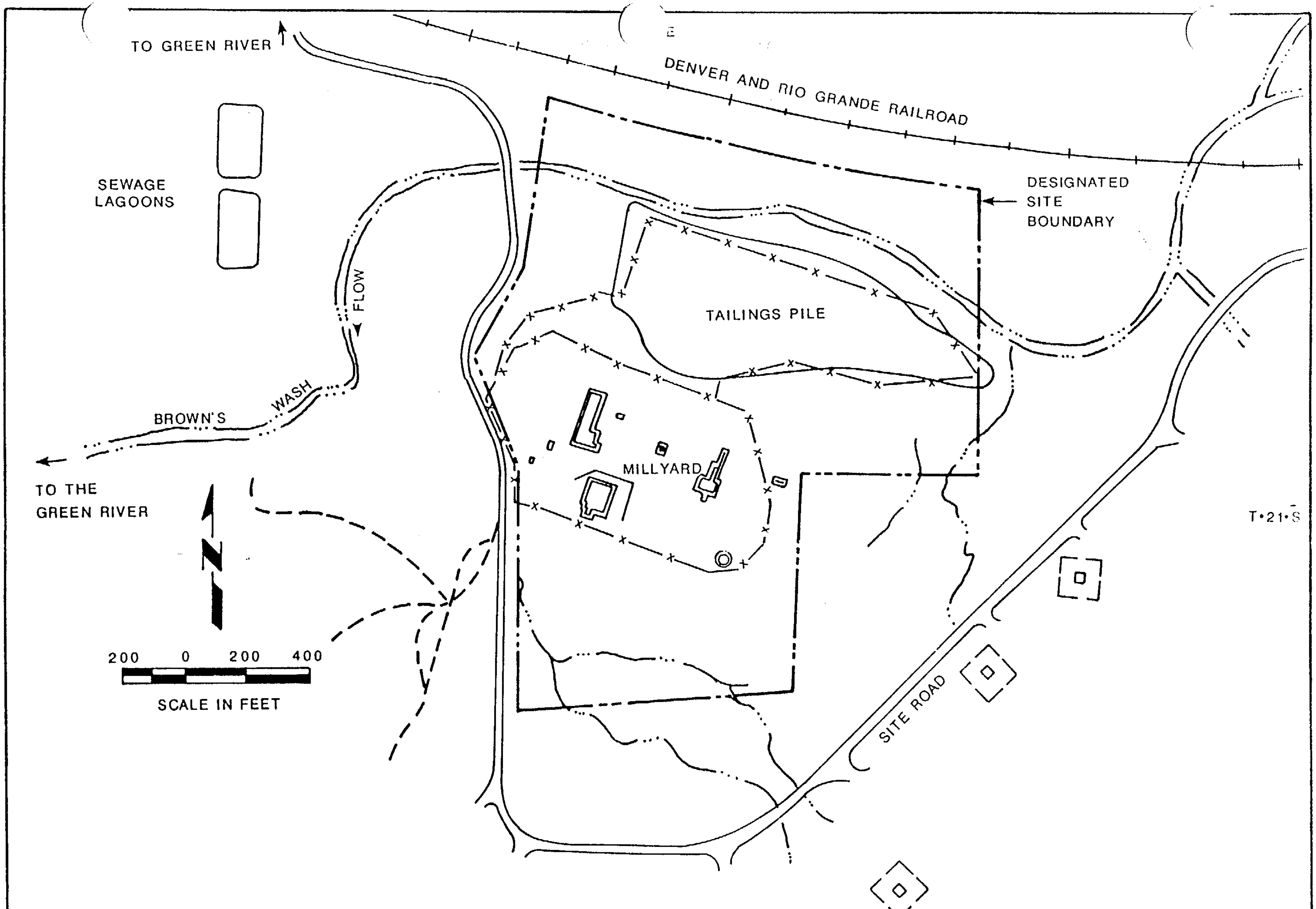


FIGURE 3.2 PRESENT CONDITIONS, GREEN RIVER TAILINGS SITE

Problem description

Three problem areas existing at the Green River site include radiation, groundwater contamination, and long-term stability. These problem areas will require remedial action in order to satisfy the intent of the UMTRCA.

Radon emissions from the site exceed the EPA standard of 20 picocuries per square meter per second (pCi/m^2s). Groundwater beneath the pile in the Brown's Wash alluvium and the Cedar Mountain Formation is contaminated. The long-term stability of the tailings and other contaminated materials is not assured because of the possibility for physical removal and/or erosion of tailings. The primary obstacle to long-term stability of the tailings at their present location is the potential for erosion by flood flows in Brown's Wash and runoff from the site vicinity.

3.1.2 Disposal site

In order to stabilize the tailings and meet the EPA standards, the tailings and other contaminated materials will be consolidated into a disposal cell located out of Brown's Wash approximately 500 feet south and 50 feet higher in elevation than the existing mill site (see Figure 3.2). The site occupies a level area that is disected by a shallow, ephemeral stream. This stream drains to the northwest, around the mill site. Bedrock is exposed in the bottom of the drainage near where the mill site fence parallels the site road.

The site surface is formed of pediment sand and gravel and is covered by sagebrush and wild forbes. A power line crosses the site area.

3.1.3 Radon cover and gravel borrow site

A source of radon cover material and small-diameter gravel has been identified in Section 2, Township 21 South, Range 16 East (see Figure 3.1). Access to this site is by Hastings Road, north of U.S. 6 & 50. The area is immediately north of the Elgin Cemetery and the western portion of the site is currently being used as a gravel borrow source. Surface topography is relatively flat. Vegetation consists of sagebrush and native grasses.

3.1.4 Rock borrow source

A larger diameter rock borrow source has been identified approximately 75 miles west of Green River site at Fremont Junction 21. Access is via I-70. The site is a rock quarry of primarily basalt boulders that has been used by the Utah Department of Transportation for construction of interstate highways.

3.2 RADIATION

This section summarizes the characterization of radioactive materials at the Green River uranium mill tailings site. The details of the characterization investigations and of the calculations leading to the summary values are contained in Appendix D, Site Characterization. Radiological data from the site and immediate vicinity have been collected in several investigations since 1976 (Appendix D, Site Characterization). The radiological data summarized here describe the background radiological conditions, increases of radiation above background due to the tailings, extent and degree of the contamination on the site and its vicinity (see Figure 3.3), and volume and average radioactivity of the contaminated materials.

3.2.1 Background radiation

Background radioactivity data provide a reference point to which levels of contamination can be compared in assessing the extent of contaminated areas requiring cleanup and the magnitude of radioactivity released from the site. Measurements of background radioactivity near Green River gave the following results (see Appendix D):

- o Background gamma exposure rates at one meter above the earth average 12 microroentgens per hour (microR/hr).
- o Background radium-226 (Ra-226) concentrations in soil near Green River average approximately one pCi/g.
- o The annual average background radon-22 (Rn-222) concentration in air at locations near Green River is one picocurie per liter (pCi/l) (TAC, 1988).

3.2.2 Existing conditions

The radioactive materials at the Green river site cause the ambient radiation levels to exceed background levels. Measurements of on-site gamma exposure rates and radon concentrations in air are summarized below (see Appendix D).

- o Gamma exposure rates on the tailings pile ranged from 30 to 112 microR/hr. Across the remainder of the site the gamma exposure rate ranged from 12 to 403 microR/hr. These measurements were taken at one meter above the surface.
- o Annual average radon measurements at the Green River tailings pile perimeter averaged 3.6 pCi/l and ranged from 1.6 to 5.9 pCi/l (TAC, 1988).
- o No measurements of radioactive air particulates were made.

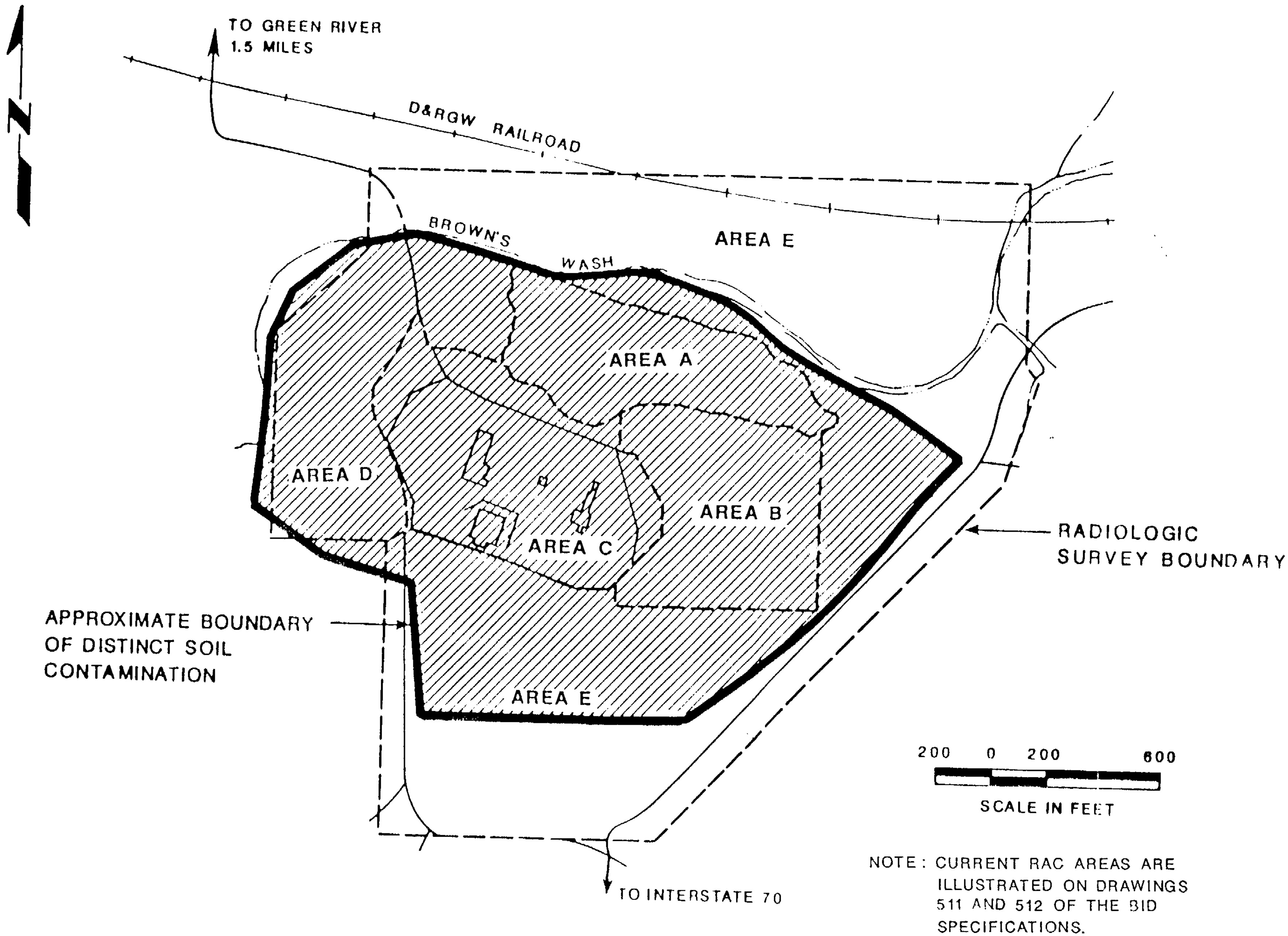


FIGURE 3.3 LIMITS OF CONTAMINATION

3.2.3 Contaminant distribution

The mill at the Green River site operated from March 1958 through January 1961 as an ore upgrader. During its operation the mill processed 183,000 tons of ore averaging 0.29 percent uranium oxide, producing an ore concentrate that was shipped to a processing plant in Rifle, Colorado. The upgrading process generated an estimated 137,000 tons of sandy tailings (no slimes) that were placed in one pile near the northeast edge of the site. An estimated 14,000 tons were carried by floodwaters down Brown's Wash in 1959, leaving approximately 123,000 tons of tailings remaining at the site. When the mill was shut down in 1961, the tailings pile was covered with approximately six inches of uncontaminated soil. The plant equipment was dismantled, and the buildings were left intact.

Initial site characterization work estimated that there are 114,000 cy of contaminated material in and around the tailings pile (Area A in Figure 3.3). This volume includes soils beneath the pile contaminated by movement of tailings liquids into the underlying natural soils. The extent of subpile contamination is bounded by the depth of the soil where the Ra-226 concentration is five pCi/g. The tailings pile covers about eight acres and the associated contaminated materials (pile and subpile) have an average Ra-226 concentration of 98 pCi/g.

The former ore storage area (Area B) covers approximately nine acres. This area contains 7200 cy of contaminated soil with an average Ra-226 concentration of 30 pCi/g.

The former mill yard (Area C) contains 18,000 cy of contaminated soil covering nearly 13 acres. The average Ra-226 concentration of these soils is 24 pCi/g. Additionally, the mill yard contains four buildings: the office building, mill building, roaster, and crusher. These buildings are surficially contaminated with windblown tailings or contaminated soil.

The windblown/waterborne contamination at the site covers all of Area D and portions of Area E. These areas cover about 30 acres and contain 46,000 cy of contaminated material. The average Ra-226 concentration of these soils is 50 pCi/g. Area D generally contains deeper contamination and higher Ra-226 concentrations than the relevant portions of Area E. Brown's Wash is considered clean and only spotty, low-level contamination exists between Brown's Wash and the railroad track.

The Remedial Action Contractor (RAC) used a different methodology to estimate the volume of contaminated material and the associated Ra-226 concentration. The RAC volume estimate for the tailings pile was 144,300 cy with a Ra-226 concentration of 104 pCi/g. The RAC volume estimate for the windblown area was 45,700 cy with an average Ra-226 concentration of 34 pCi/g. The total volume of contaminated material at the site is 189,900 cy with an average Ra-226 concentration of 87 pCi/g. An additional 10,000 cy of contaminated material is expected to be generated by remedial action activities at vicinity properties. The RAC volume estimates are summarized in Table 3.1. These volume estimates are based on the areas depicted in drawings 511 and 512 of the subcontractor bid specifications in Appendix F and on subsequent calculations of contaminated material stockpiles.

Additional quantities of contaminated material were discovered at the site and at vicinity properties. The latest quantities are described in the following section.

3.2.4 Volumes of contaminated material

Table 3.1 summarizes the extent, average Ra-226 concentration, and volume of contaminated materials based on the RAC data interpretation. The volume estimates in each area are based on the depth at which the Ra-226 concentration is five pCi/g.

3.3 GEOLOGY, GEOMORPHOLOGY, AND SEISMICITY

3.3.1 Introduction

Detailed descriptions of the geology, geomorphology, and seismicity at the Green River site are presented in Appendix D, Site Characterization. Both the existing tailings pile and the proposed alternative disposal area are described. The purposes of the investigations described was basic site characterization and identification of potential geologic hazards that could affect long-term stability of the pile. Subsequent engineering studies, such as analysis of hydrologic and liquefaction hazards, use the data developed in these studies. The geomorphic information was

Table 3.1 Volumes of contaminated material at the Green River site

Description	Volume (cy)	Area (acres)	Average Ra-226 concentration (pCi/g)
Tailings pile	204,249	13.7	104
Other contaminated	138,217	38.4	34
Vicinity property material	39,295	NA[a]	NA[a]
Total[b]	381,761	52	c

[a]NA = not available.

[b]Average Ra-226 concentration is volume-weighted; quantities stated in excavated cubic yards; total in-place quantity of tailings and other contaminated material in the cell is 339,377 cy.

[c]The average Ra-226 concentration for all materials has not yet been calculated. The average for the 200,000 cy quantified in the February 1988 RAP was 87 pCi/g.

also used in the design of effective erosion protection. Studies of the regional and local seismotectonic setting, which included a detailed search for possible capable faults within a 65-kilometer (km) radius of the site, provided the basis for estimation of seismic design parameters.

Wherever major structural or seismotectonic features, such as the boundaries of seismotectonic provinces, lay outside the 65-km site radius they were generally characterized based on previously published studies, communications with researchers active in the area, and the like. If such information indicated that the features may have a significant impact on the seismic design parameters, they were subjected to the appropriate investigations and are included in the RAP.

The scope of work performed included the following:

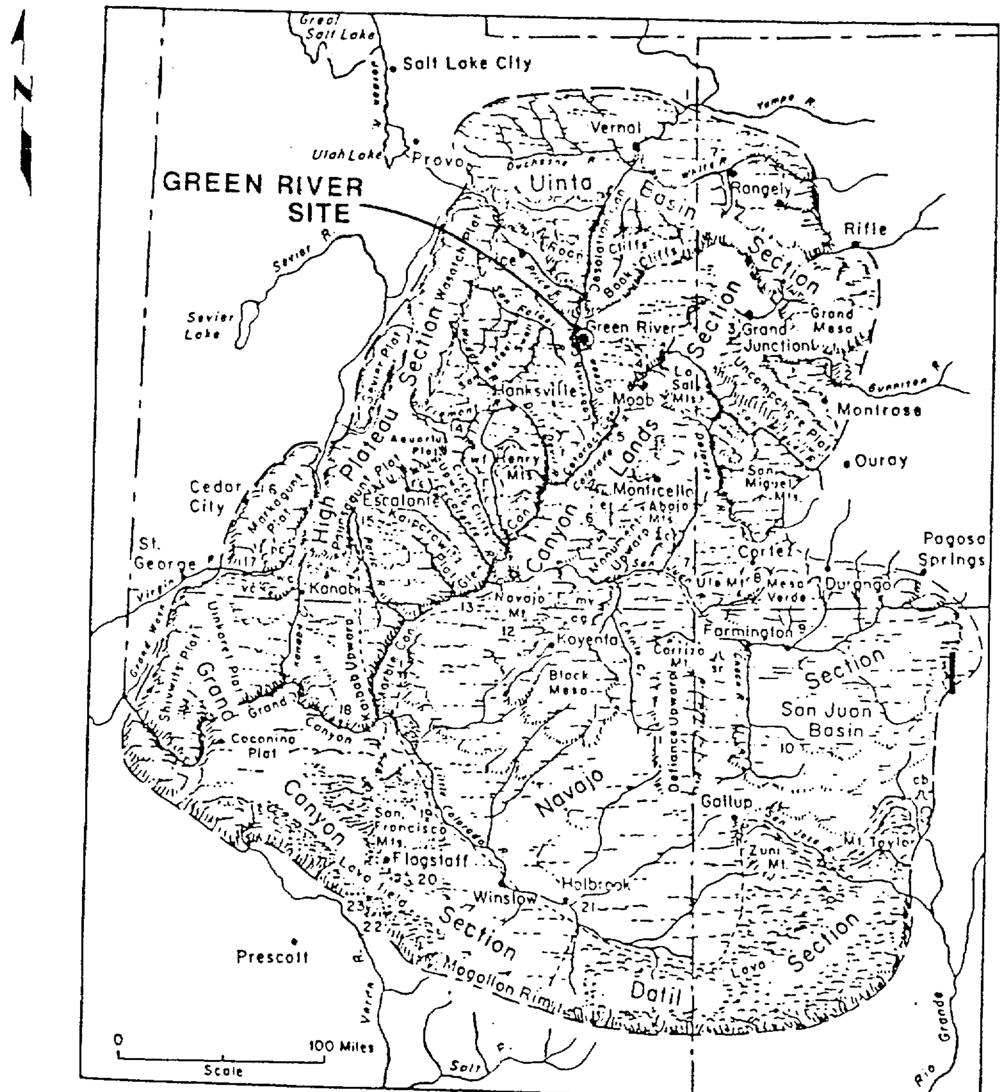
- Compilation and analysis of previously published and unpublished geologic literature and maps.
- Review and analysis of historical and instrumental seismic data.
- Review of site-specific subsurface geologic data, including logs and samples from exploratory boreholes and test pits advanced in the site area.
- Photogeologic interpretation of existing LANDSAT and conventional aerial photographs.
- Low-sun-angle aerial reconnaissance of the site region.
- Ground reconnaissance and mapping of the site region.
- Detailed mapping of the site area.
- Communications with various geologic investigators concerned with problems of the local and regional geology.

This study is substantially in compliance with the NRC's Standard Review Plan and/or 10 CFR 100, Appendix A, IV (Required Investigations).

3.3.2 Geologic setting

Physiography

The Green River site is in the northern part of the Canyon Lands section of the Colorado Plateau physiographic province (Hunt, 1967; Figure 3.4). The Book Cliffs, a few miles to the north, form the southern boundary of the Uinta Basin section. The Canyon Lands section is characterized by large structural upwarps and intervening basins formed mostly in Upper Paleozoic and Lower Mesozoic sandstones and shales. In the Uinta Basin section, thick



National Parks and Monuments

1. Dinosaur Nat. Mon.
2. Black Canyon of the Gunnison Nat. Mon.
3. Colorado Nat. Mon.
4. Arches Nat. Mon.
5. Canyonlands Nat. Park
6. Natural Bridges Nat. Mon.
7. Hovenweep Nat. Mon.
8. Mesaverde Nat. Park
9. Aztec Ruins Nat. Mon.
10. Chaco Canyon Nat. Mon.
11. Canyon de Chelly Nat. Mon.
12. Navajo Nat. Mon. (Betatakin and Kiet Seel)
13. Rainbow Bridge Nat. Mon.
14. Capitol Reef Nat. Mon.
15. Bryce Canyon Nat. Park
16. Cedar Breaks Nat. Mon.
17. Zion Nat. Park
18. Grand Canyon Nat. Park
19. Wupatki and Sunset Crater Nat. Mons.
20. Walnut Canyon Nat. Mon.
21. Petrified Forest and Painted Desert Nat. Mon.
22. Montezuma Castle Nat. Mon.
23. Tuzigoot Nat. Mon.

Escarpments at South End of High Plateaus

pc Pink Cliffs
wc White Cliffs
vc Vermilion Cliffs

Other Prominent Features

wf Waterpocket Fold
er Elk Ridge
cr Comb Ridge
mv Monument Valley
ag Agathla Peak
sr Shiprock
cb Cabezon Peak

REF: HUNT, 1967

FIGURE 3.4 PHYSIOGRAPHIC SKETCH MAP OF THE COLORADO PLATEAU SHOWING LOCATION OF THE GREEN RIVER SITE

Tertiary and Cretaceous sedimentary formations overlie the older rocks. The most prominent land forms in the site region are broad mesas and pediment surfaces, narrow, rock-walled gullies, and deeply incised canyons.

The site region is drained by the Green River, a major tributary of the Colorado River, which rises in western Wyoming and drains a large area of Wyoming, Colorado, and northeastern Utah. The Green River passes within about 0.5 mile west of the site. Brown's Wash, an intermittent tributary to the Green River, drains an area of about 85 square miles north and east of the site (FBDU, 1981) and flows along the north side of the existing tailings pile.

Elevation in the site region ranges from about 4000 to 9000 feet above mean sea level. Elevation of the site area varies from about 4050 to 4200 feet. To the north of the site area, in the Book Cliffs, and to the west, on the San Rafael Swell, elevations range up to 8000 or 9000 feet.

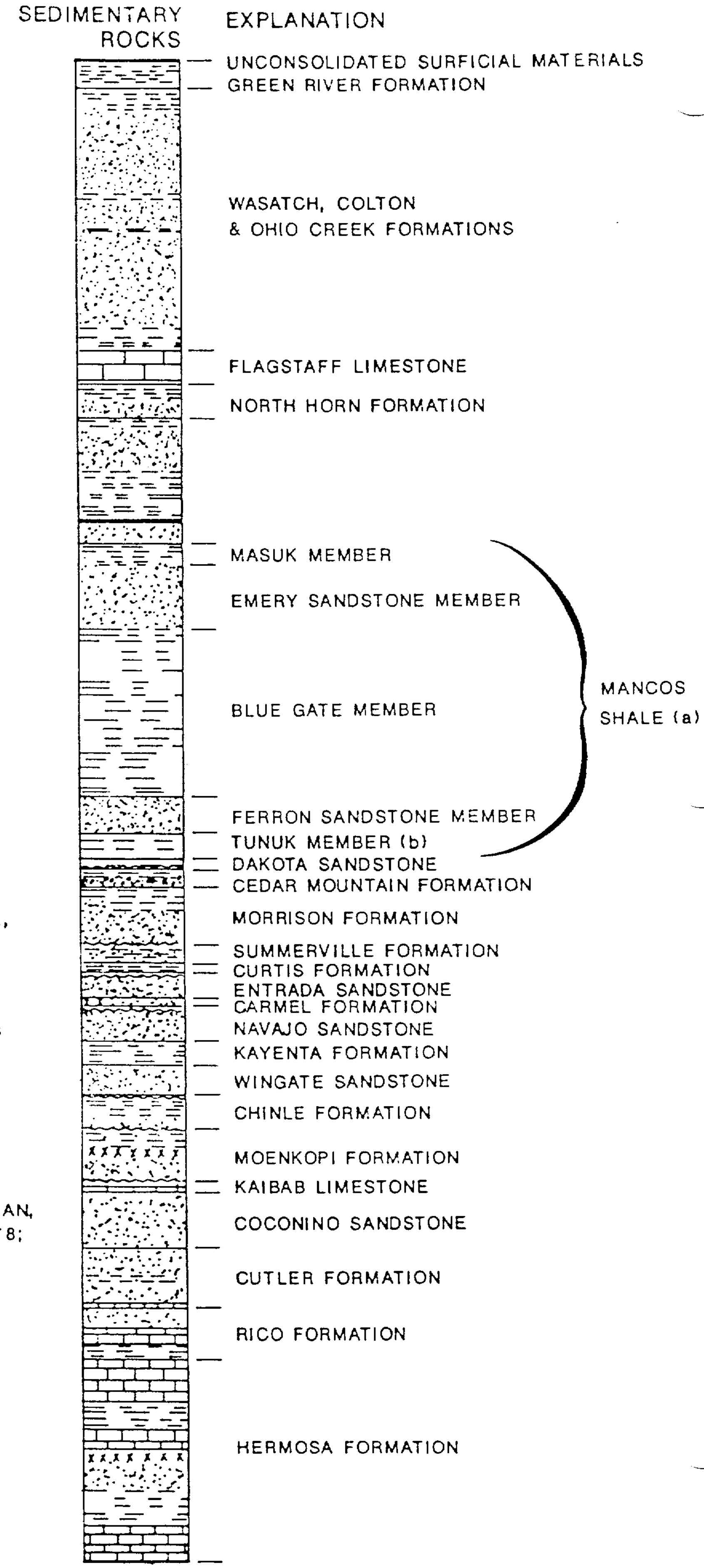
Major physiographic features of the site region are the Mancos Shale Lowland, which includes the site area, and the Book Cliffs, Roan Plateau, San Rafael Swell, Green River Desert (also referred to as the San Rafael Desert), and Salt Anticline regions (Stokes, 1977).

Bedrock units

Bedrock in the site region consists almost entirely of layered sedimentary units, ranging in age from late Paleozoic to early and middle Tertiary (Figure 3.5) (Lines, 1984; Osterwald et al., 1981; Hintze, 1980; Witkind et al., 1978; Cashion, 1973; Williams and Hackman, 1971a; Williams, 1964). These units consist mainly of sandstone, shale, and mudstone, with lesser amounts of salt, gypsum, potash, limestone, and conglomerate. Units generally decrease in age from south to north across the site region.

Units ranging in age from late Paleozoic (Pennsylvanian-Permian) to Mesozoic are exposed in the San Rafael Swell, Monument Uplift, and Paradox Basin regions to the southwest, south, and southeast, respectively, of the site. The Green River Desert (San Rafael Desert) and Mancos Shale Lowland areas, which include the Green River site area, are underlain by units primarily of mid- to late-Mesozoic (Jurassic-Cretaceous) age. To the north, the Book Cliffs-Roan Cliffs and Uinta Basin areas are underlain by sedimentary units of Tertiary (Paleocene-Eocene) age, generally dipping northward at gentle angles toward the east-west-trending axis of the Uinta Basin.

Quaternary deposits in the site region generally consist of thin, discontinuous covers of alluvial deposits, pediment and terrace gravels, eolian deposits, and colluvium.



LEGEND

ALLUVIAL, EOLIAN & GLACIAL DEPOSITS OF QUATERNARY AGE, UNDIVIDED

CONFORMABLE CONTACT

UNCONFORMITY

SHALE, SILTSTONE OR MUDSTONE

SANDSTONE

CONGLOMERATE

LIMESTONE

X X X GYPSUM

COAL

VERTICAL SCALE

0
500
1000
1500
2000

NOTE:

(a) The upper part of Mancos Shale (Masuk, Emery Sandstone, & Blue Gate Members) are undivided in site region.

(b) The stratigraphic position of the site is near the Tunuk & Cedar Mountain Contact.

REF: WILLIAMS, 1964; WILLIAMS & HACKMAN, 1971a; CASHION, 1973; WITKIND, et al, 1978; HINTZE, 1980; OSTERWALD, et al, 1981; LINES & OTHERS, 1984.

FIGURE 3.5

REGIONAL STRATIGRAPHIC COLUMN

Bedrock units exposed in the site area consist of the Tununk Shale Member of the Mancos Shale, the Dakota Sandstone, and the Cedar Mountain Formation, all of Cretaceous age.

The Tununk Shale Member of the Mancos Shale consists of dark gray, grayish brown, and black carbonaceous shale, interbedded with thin lenses of pale yellow sandstone. Exposures of this unit in the site area are strongly to moderately weathered and commonly altered to medium-plasticity silty or sandy clay. A fine shaly cleavage is commonly well-developed parallel to bedding.

Lying at the base of Tununk Shale and underlying a large part of the site area is a series of beds of sandstone, conglomerate, and limestone that are correlative to the Dakota Sandstone. The Dakota Sandstone contains distinctive beds of light gray, brown, and white, laminated to thinly bedded and occasionally banded sandstone and arkosic sandstone, varying from fine to coarse-grained; thickly bedded to massive conglomerate cross-bedding is common and rapid lateral facies changes are characteristic of the unit.

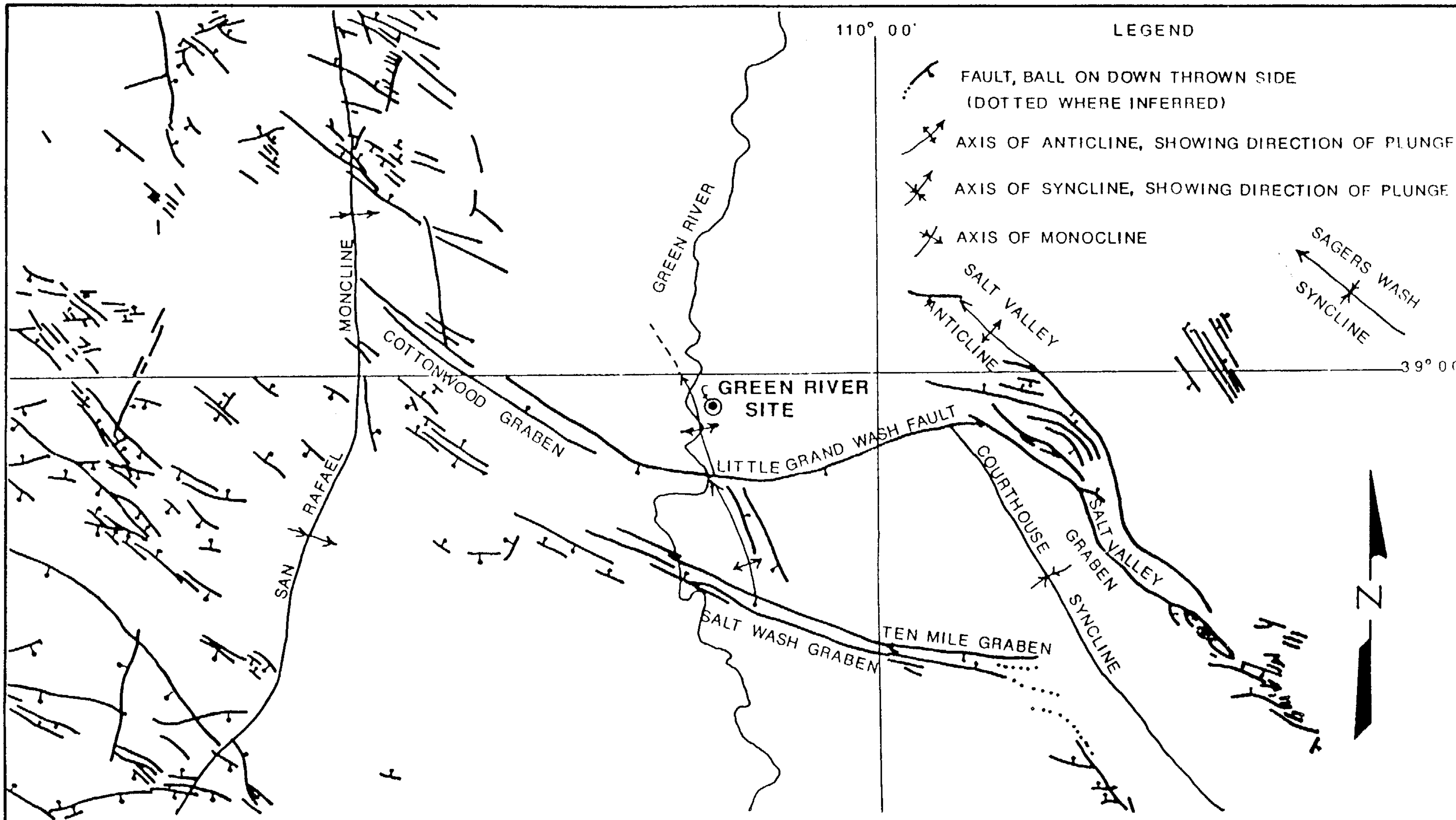
The Dakota Sandstone is unconformably underlain in the site area by a series of interbedded mudstones, shales, sandstones, limestones, and conglomerates of the Cedar Mountain Formation. This formation is correlative to the Burro Canyon Formation of western Colorado. In the site area it consists predominantly of grayish brown shaly mudstone and light gray very fine- to fine-grained calcareous mudstone, with minor sandstone and conglomerate.

Structural geology

The major structural and tectonic features of the Green River site region are the San Rafael Swell, the San Rafael Desert (Green River Desert), the Uinta Basin, the salt anticlines of the Paradox Basin, and the Monument Upwarp (Figure 3.6). These structures are primarily Laramide (Late Cretaceous-Eocene) in age.

The Green River site area lies on the north-plunging nose of a shallow anticlinal fold whose axis approximately coincides with the course of the Green River (Hintze, 1980; Williams and Hackman, 1971a,b). The nose of the anticline is repeated by an arcuate, east-west-trending normal fault that lies about 2.5 miles south of the site. Several thousand feet of Jurassic and Cretaceous strata are repeated by the fault. Crystal Geyser, a naturally occurring carbon dioxide-charged spring, occurs where this fault crosses the Green River. The geyser apparently occurs at a local relief point for carbon dioxide-charged water trapped in the Navajo Sandstone (Baer and Rigby, 1978). A narrow, arcuate graben, whose trace parallels the above fault, crosses the Mancos Shale Lowland several miles further to the south.

Bedding at the site is approximately horizontal with slight northward dips (less than five degrees), but some local folding is present in the site area. Jointing is common in the more resistant



REF: WILLIAMS, 1964; WILLIAMS & HACKMAN, 1971b;
CASHION, 1973; & WITKIND et al., 1978

FIGURE 3.6 STRUCTURAL GEOLOGIC SKETCH MAP OF GREEN RIVER SITE AREA

units, most commonly displaying north-northwest trends. No faults with significant displacement are known in the immediate site area.

Quaternary geology and geomorphology

Geomorphic processes acting on the site region reflect the influence of the prevailing arid to semiarid climate, variations in bedrock type, and the effects of an epeirogenic uplift of the Colorado Plateau, which began during the Miocene and has evidently continued to the present day. Erosion by fluvial, eolian, and mass-wasting processes, and transport of sediment away from the region by streams have been the dominant geomorphic processes throughout Holocene time, at least. Quaternary deposits and soils of the region record some interruptions, probably climatically induced, in the long-term stream incision process (Woodward-Clyde Consultants, 1982).

Surficial deposits are thin and discontinuous over most of the site region, and bedrock is generally exposed at or near the surface. As a result, the surface topography and landforms reflect the structure and stratigraphic variability of the underlying bedrock. In areas where relatively durable sandstones are exposed at the surface, weathering has produced a fantastic variety of landforms, including cliffs, monuments, pinnacles, fins, alcoves, tanks, natural bridges, and arches. In areas underlain entirely by shale or where interlayered sandstones and relatively less durable shales are exposed, erosion produces rugged badlands topography.

Quaternary surficial deposits consist of alluvium and colluvium, eolian deposits, and terrace and pediment gravels. Large-scale subsidence features in the salt anticlines of the Paradox Basin result from the upward-doming of late Paleozoic salt and gypsum and their gradual removal by ground and surface waters. Glacial processes have not had a direct impact on the site region, although erosion rates were evidently strongly influenced by Pleistocene climate changes.

3.3.3 Seismicity and tectonics

The Green River site lies within the relatively stable interior portion of the Colorado Plateau, about 50 to 100 miles east of the highly active Intermountain Seismic Belt. Most of the major structural and tectonic features of the site region, with the exception of the Intermountain Seismic Belt, are Laramide uplifts and basins. These features are generally considered to be inactive under the present seismotectonic regime.

The site area lies within the boundaries of the Paradox Basin, which is characterized by complex systems of northwest-trending normal faults and landslide and slump features. Typical salt anticlinal collapse features extend to within about 12 miles of the site. These features have been active during Quaternary time and may be active today. However, since they result from very gradual processes of salt solution and flowage, they are probably not capable of generating large earthquakes. Kirkham and Rogers (1981) estimate the maximum earthquakes possible on these features to be about magnitude 5.

The largest recorded events in the site region have been of magnitude (m_b) 4.0 to 4.2. The majority of these are either known or suspected to be related to mining activities.

The lack of large tectonic earthquakes and known active features, and the distance separating the site from highly active regional features such as the Intermountain Seismic Belt, indicate a relatively stable setting.

Recommended seismic design parameters

The recommended design earthquake for the Green River site is an event of magnitude (M_L) 6.2 occurring at a radial distance of 15 kilometers (9.5 miles) from the site. This event is a "floating earthquake" and a design fault is not specified. The resulting on-site acceleration of 0.21g (determined from the acceleration-attenation relationship of Campbell, 1981) is recommended as the design acceleration. The duration of strong ground motion (>0.05g) during occurrence of the design earthquake was estimated using the magnitude/epicentral distance/duration curves of Krinitzsky and Chang (1977). At the existing tailings pile, considered to be a soil site, the duration is estimated to be about 16 to 18 seconds. The alternative disposal site is considered to be a bedrock site and the duration of strong ground motion is estimated to be about ten seconds.

Potential for on-site fault rupture

Results of the detailed analysis of potential design faults in the site region do not indicate that capable faults are present within 65 kilometers (40 miles) of the site. Review of the historical and instrumental seismic records does not indicate any correlation of seismic activity with known or suspected faults. In addition, geomorphic surfaces in the site area ranging from Holocene to late Quaternary in age show no signs of tectonic disturbance, indicating that the area has been stable during at least the last 35,000 to 70,000 years.

Liquefaction potential

The existing tailings rest on a layer of partly saturated Holocene alluvium about 10 feet thick, which may be susceptible to liquefaction under ground motion caused by the design earthquake. However, the alternative tailings disposal area is on bedrock mantled by a thin layer of unsaturated and partially cemented pediment gravels. This area is not susceptible to liquefaction.

Induced seismicity

Low-intensity seismic vibrations may be experienced periodically in the site area as a result of mining and oil and gas withdrawal in the surrounding region. As the pile is designed to be stable in the event of the design earthquake, it will be stable under those events as well. There are no large reservoirs in the site region at present. Future development of large reservoirs on the Green River is unlikely since this would result in inundation of agricultural, residential, and recreational areas. In addition, suitable impoundment areas for large reservoirs may not exist. The potential for reservoir-induced seismicity at the site, therefore, appears to be extremely low during the 1000-year design life.

Volcanic hazard

No intrusive or volcanic rocks crop out anywhere within the 65-kilometer (40-mile) radius study region surrounding the site (Witkind et al., 1978; Cashion, 1973; Williams and Hackman, 1971a; Williams, 1964). None are known to exist within the stratigraphic column underlying the site, above the Precambrian basement. Other indications of a potential for volcanic activity, such as known geothermal resources, high heat flow, or thermal springs or geysers, are also absent.

3.3.4 Geomorphic hazards

The most significant hazard to the stability of the proposed alternative disposal area results from existing gully systems that head within the proposed pile area. Other gully systems that drain small areas southeast of the proposed pile extend along the south side. Development of new gully systems from the former mill site area may also occur during the next 1000 years and could impact site stability. These potential hazards can be mitigated by suitable safety measures (such as aprons) in pile design.

Minor processes that will affect the tailings disposal facility include the following:

- Rainsplash and sheet wash.
- Wind action.
- Chemical weathering of limestone and limey sandstone.
- Shrink/swell effects of shales.
- Frost heave, solifluction, and downslope creep of unconsolidated materials.

The potential long-term impacts of these processes can be effectively mitigated by suitable safety measures in pile design and construction.

Potential for ground subsidence induced by salt solution

The potential for significant subsidence due to salt solution and removal at depth during the proposed design life was carefully considered during the investigation. The potential hazard to site stability does not seem to be significant.

The salt and gypsum-bearing Paradox member of the Pennsylvanian Hermosa Formation is present in the stratigraphic column beneath the site. The occurrence of highly saline groundwater at Crystal Geyser also indicates ongoing salt solution at depth. Furthermore, the location of the site within the boundary of the Paradox Basin and within 10 to 20 miles of large-scale subsidence features in Salt Valley indicates that a potential for subsidence may exist.

However, the site area is near the margins of the Paradox Basin, rather than in the interior, and the amount of salt thought to be present in the area is rather small. None of the conspicuous evidences of subsidence observed in other areas, such as northwest-trending collapsed anticlines, normal faults, and Toreva-block landslide systems, are present near the site.

It does not appear that any significant amounts of subsidence or major differential movements are occurring in the site area at present. Therefore, salt solution-induced subsidence does not appear to present a hazard to site stability during the proposed design life.

3.3.5 Potential impact of future natural resource development

Stratigraphic units that underlie the site area are known to contain economic deposits of uranium and vanadium ores, oil and gas, gypsum, salt, potash, and brines in other areas. Small amounts of these materials may be present in the site area as well, but no economic deposits are known.

No development of uranium and vanadium ores has taken place from the Green River area to date. The nearest known economically mineable deposits are in the Thompson area, 25 to 30 miles to the east, and the San Rafael River mining district, about 12 miles to the west. Units that may contain these ores, such as the Morrison Formation, are present beneath the site but there is no known evidence of development potential. The depth of burial of the Morrison and other potential ore-bearing units will probably preclude economical exploration and development of uranium and vanadium from beneath the site during the foreseeable future.

Little exploration and development of oil and gas resources has occurred to date from the Mancos Shale Lowland area that includes the site. Though some Paleozoic units that contain oil and gas are present elsewhere, the lack of structural traps probably precludes significant deposits. The Elgin Well, drilled in 1891, is the only exploratory well in the site area to date. It did not encounter oil or gas.

Salt, gypsum, potash, and brines beneath the site area are evidently of small volume and too deep to be of potential economic value.

3.4 GEOTECHNICAL

3.4.1 Tailings

Subsurface investigation

The Green River tailings pile was characterized by drilling five borings and excavating three test pits on the pile. The locations of these boreholes and test pits are presented in Figure 3.7. Logs of the borings and test pits are in Appendix D, Site Characterization, of this RAP.

Borings were advanced using standard geotechnical drilling and sampling techniques. These included drilling with hollow stem augers, and sampling at near continuous intervals with the Standard Penetration Test (SPT) and, on occasion, a 2.5-inch inside-diameter ring-lined split-barrel sampler. The SPT tests were conducted according to ASTM 1586 procedures. Samples were driven with a 140-pound weight dropped 30 inches. The mechanism is known as a "Safety Hammer" and was lifted and released by a rope wrapped two turns around a pulley, or a "Cathead." Standard "A" rods were used in driving the sampler as all borings were less than 50 feet deep.

The borings were logged by a field engineer who recorded changes in drilling lithology and blow counts. Water levels were recorded during the drilling operations.

Tailings stratigraphy

Tailings are divided into three categories according to the size of the particles. The three designations are:

- o Sand.
- o Sand-slime.
- o Slime.

At Green River the slimes were removed for upgrading at Rifle, Colorado, leaving only the sand tailings. Sand tailings, as used here, refers to those tailings with up to 30 percent passing the No. 200 sieve. In fact, most of the Green River pile contains

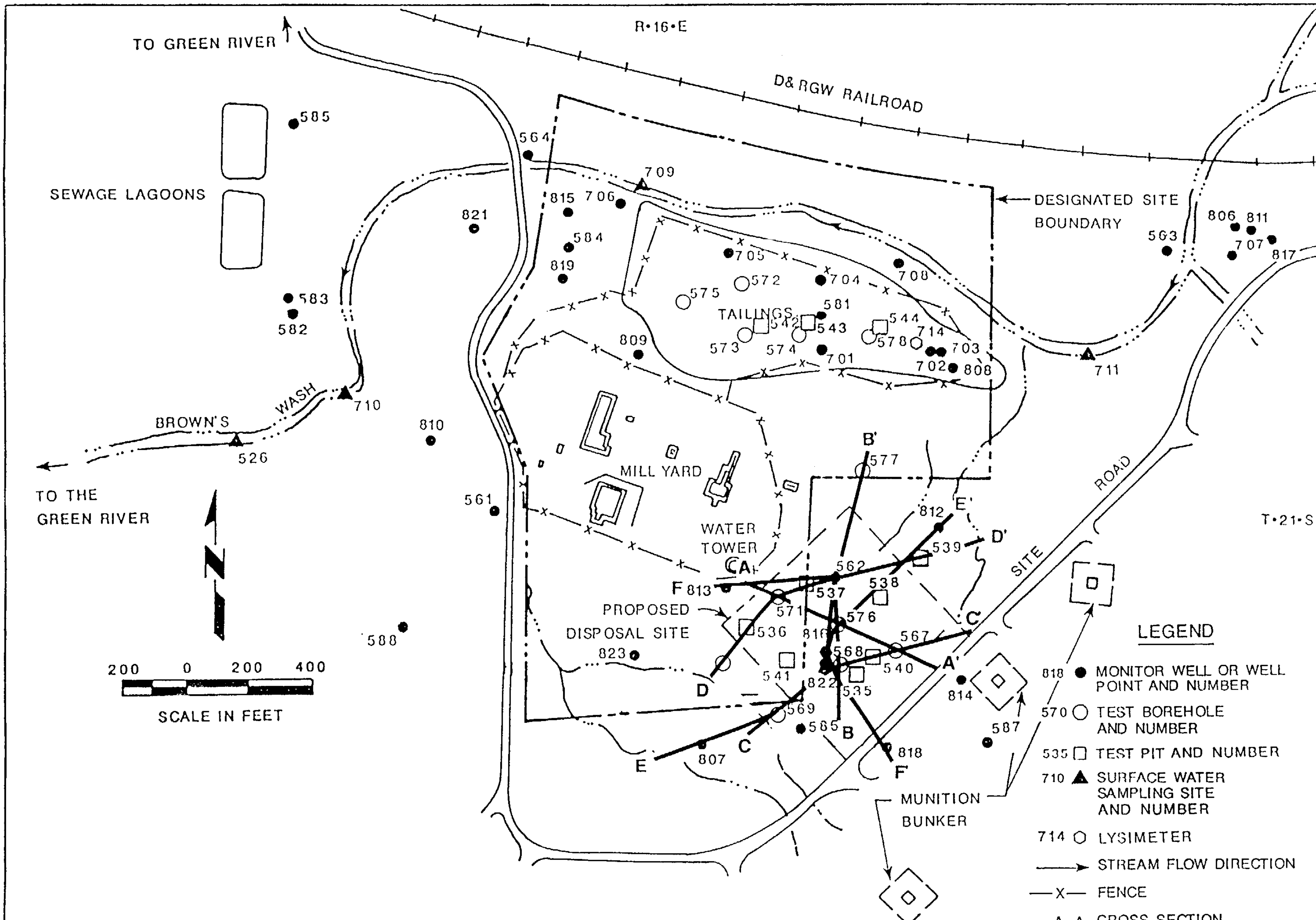


FIGURE 3.7 GREEN RIVER BORING, TEST PIT AND CROSS SECTION LOCATIONS

less than 20 percent passing the No. 200 sieve. The Unified Soil Classification System (USCS) classifies the material as silty or clayey sand: SP-SM, SP-SC, SM, and SC.

Due to the uniformity of material within the Green River tailings pile, only a single cross section has been developed and is shown on Figure 3.8. The location of this section is shown on Figure 3.7. The tailings are covered with six inches of decomposed Mancos Shale and are underlain by alluvium of Brown's Wash. The water table, as measured during drilling activities, is below the tailings-subsoil interface.

Moisture contents within the tailings pile are relatively low and range from 1.2 to 6.4 percent. Blow counts from SPT tests range from four to 16, which correlates with a loose to medium-dense compactness. Groundwater was not encountered within the tailings.

3.4.2 Disposal area foundation soils and windblown material

Subsurface investigation

The Green River disposal area was initially characterized by drilling eight borings and excavating seven test pits. The locations of all borings and monitor wells are shown on Figure 3.7. Logs of the borings and test pits are presented in Appendix D, Site Characterization. An additional 11 monitor wells were installed during a final investigation phase, of which six provided further stratigraphic data for the disposal area foundation soil and rock. The initial borings were drilled using the same techniques described for borings on the pile. Logging procedures were also the same. Boring number 562 was extended into bedrock using NX-sized rock coring techniques. The final borings were drilled using a rotary rig with air to produce an eight-inch diameter borehole. Six of these borings produced HQ rock cores.

Disposal area foundation soils and windblown material

Soils underlying the site were classified according to the USCS as shown in Appendix D (Figure D.4.12). Classification procedures used followed ASTM 2487. Cross sections of the foundation soils were developed from borehole and test pit data and are presented in Figures 3.9 through 3.14. The soils underlying the site consist of from five to 16 feet of loose to dense silty or clayey sand alluvium. Large lenses of clay are contained within the layer. Dense to very dense sand and gravel alluvium underlies these near-surface soils. The soils in turn overlie bedrock consisting of coarse conglomerate, sandstone of the Dakota Sandstone, and shales of the Cedar Mountain Formation. These near-surface soils lie within the area of windblown contamination and are considered representative of this material.

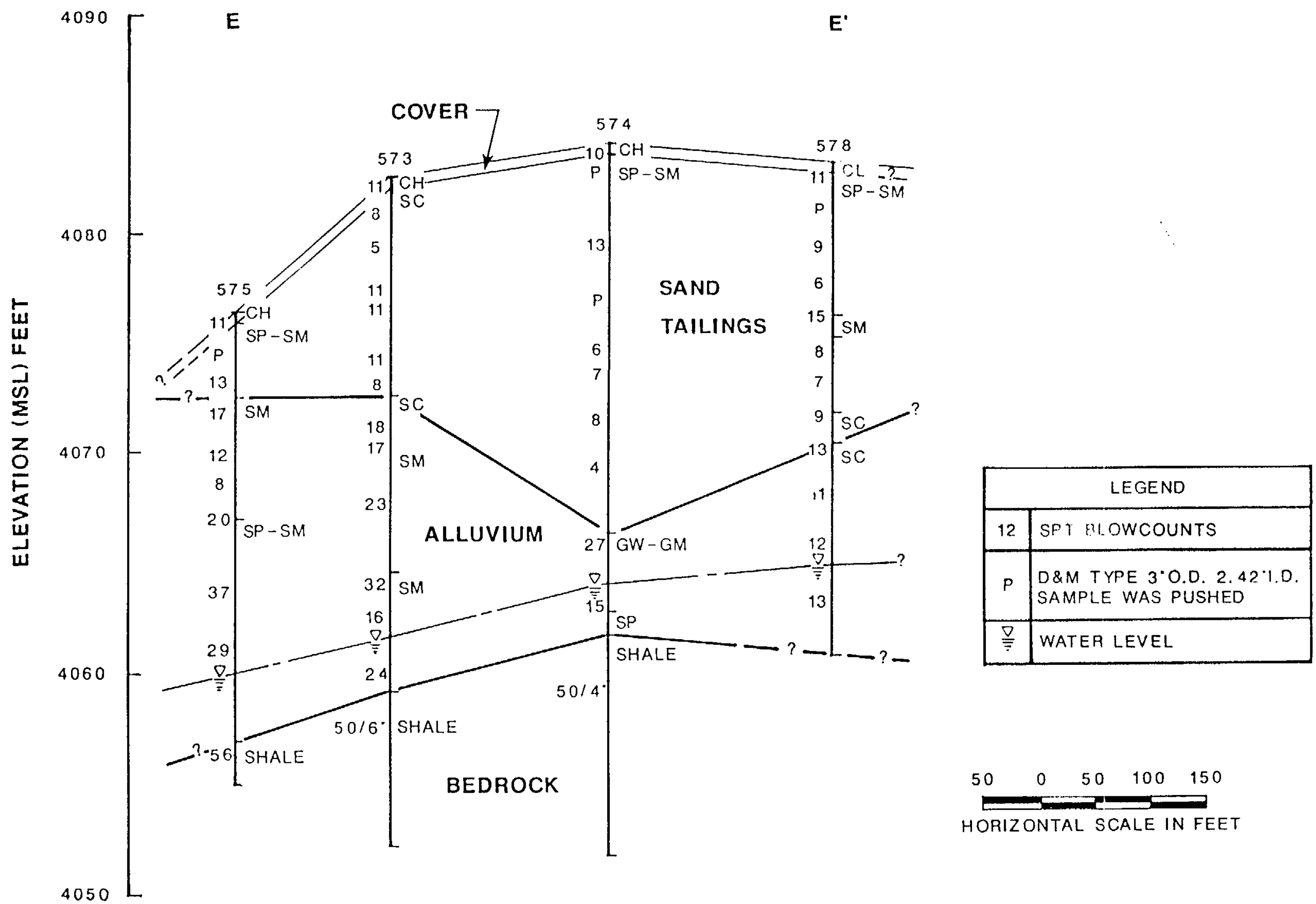
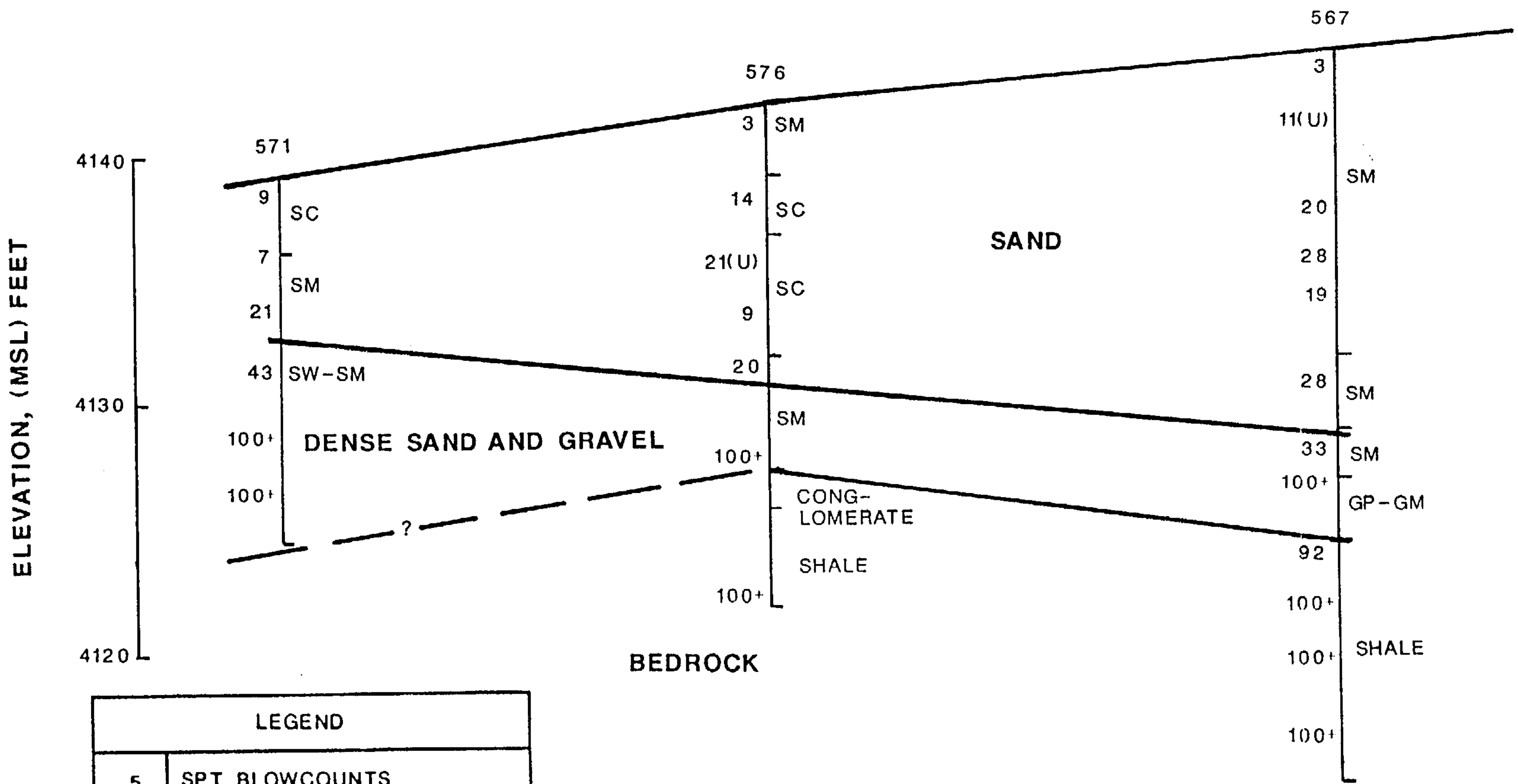


FIGURE 3.8 TAILINGS PILE CROSS SECTION E-E'



LEGEND	
5	SPT BLOWCOUNTS
7 U	BLOWCOUNTS FOR 3" O.D. 2.42" I.D. RING LINED DAMES & MOORE TYPE SAMPLER

FIGURE 3.9 GREEN RIVER SITE CROSS SECTION A – A'

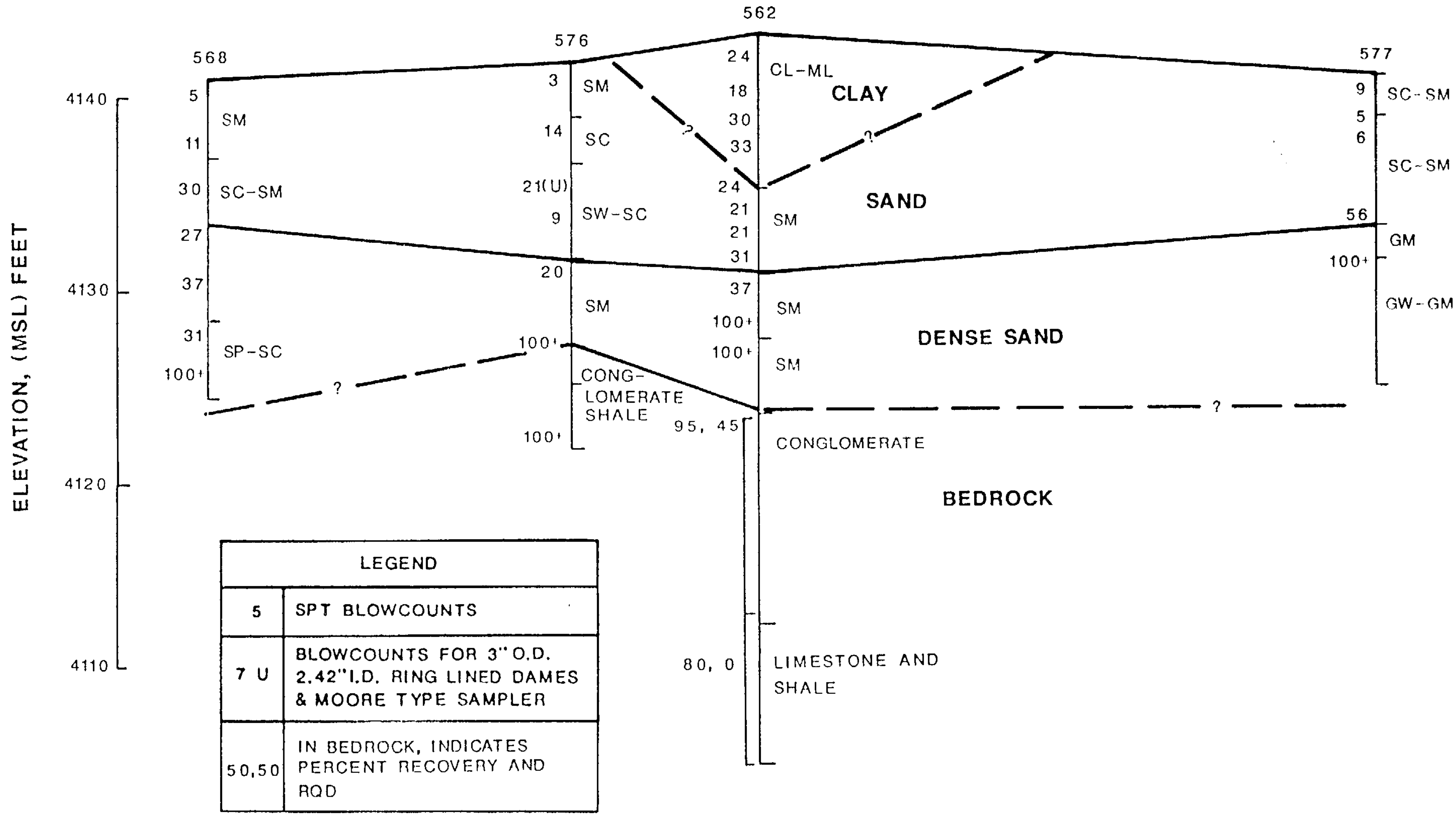


FIGURE 3.10 GREEN RIVER SITE CROSS SECTION B - B'

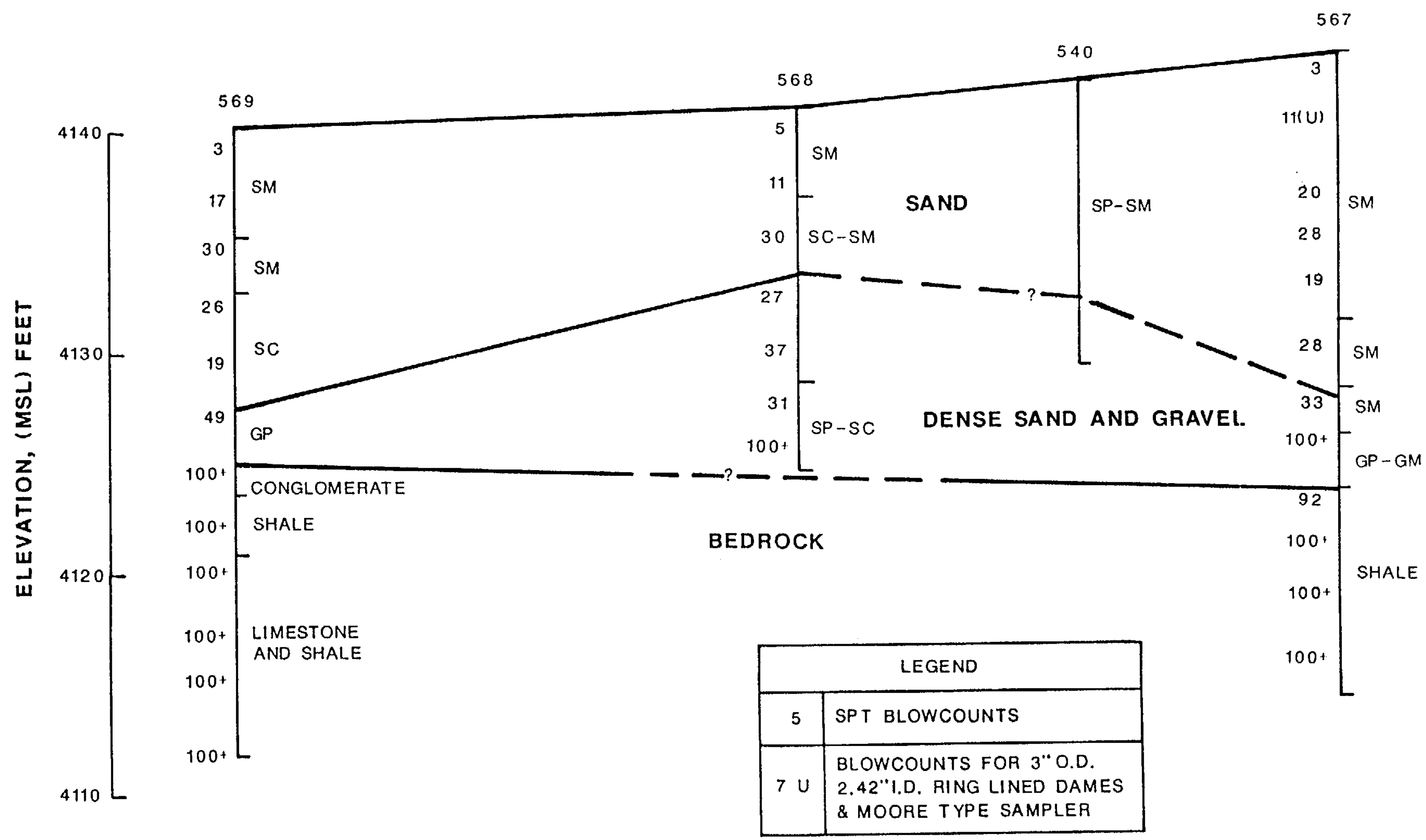
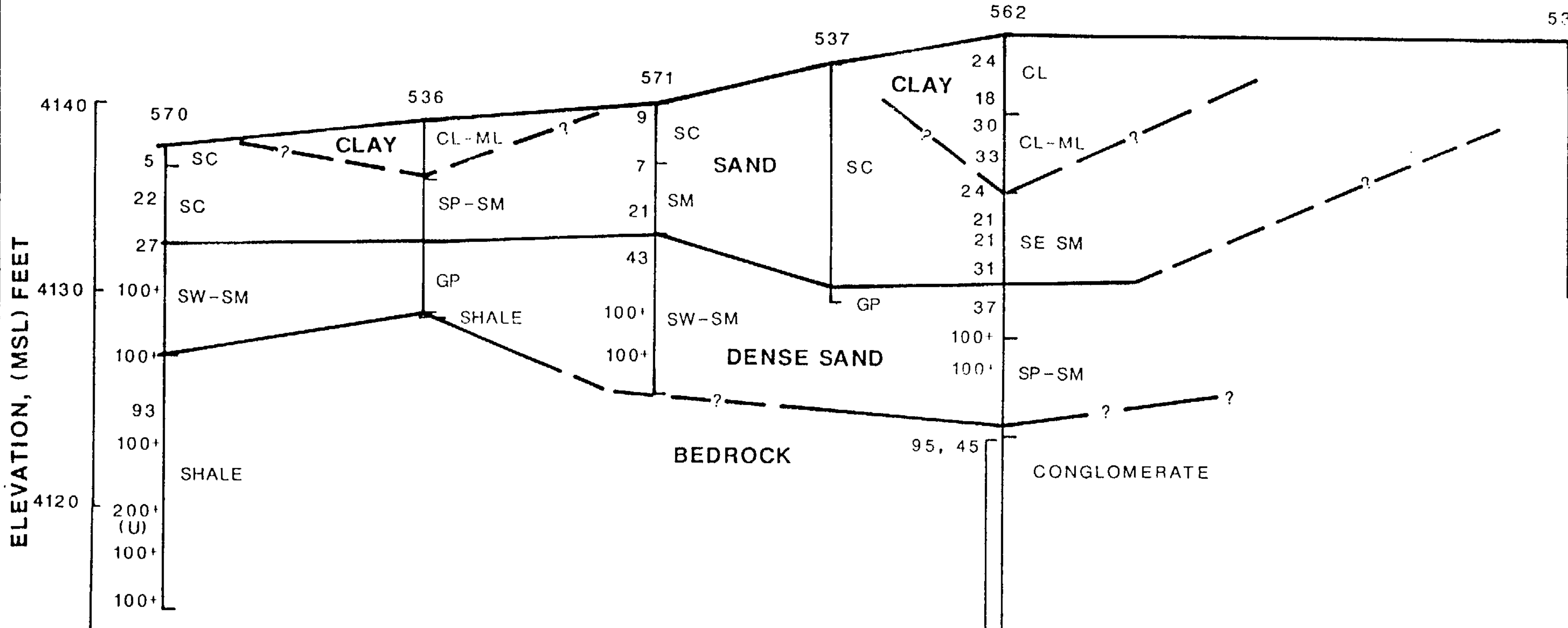


FIGURE 3.11 GREEN RIVER SITE CROSS SECTION C - C'



LEGEND	
5	SPT BLOWCOUNTS
7 U	BLOWCOUNTS FOR 3" O.D. 2.42" I.D. RING LINED DAMES & MOORE TYPE SAMPLER
50,50	IN BEDROCK, INDICATES PERCENT RECOVERY AND RQD

FIGURE 3.12 GREEN RIVER SITE CROSS SECTION D - D'

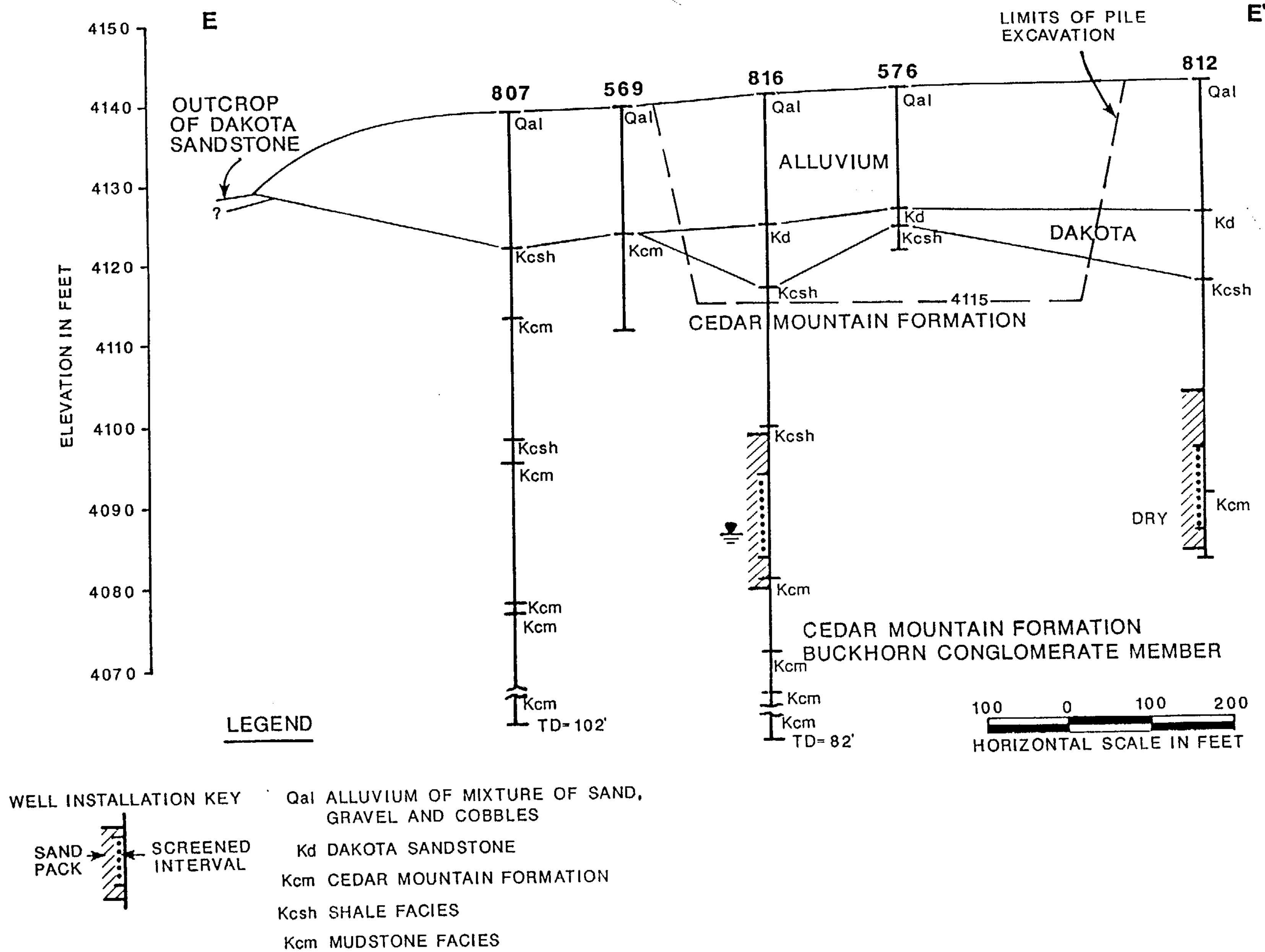


FIGURE 3.13
GREEN RIVER SITE CROSS SECTION E-E'

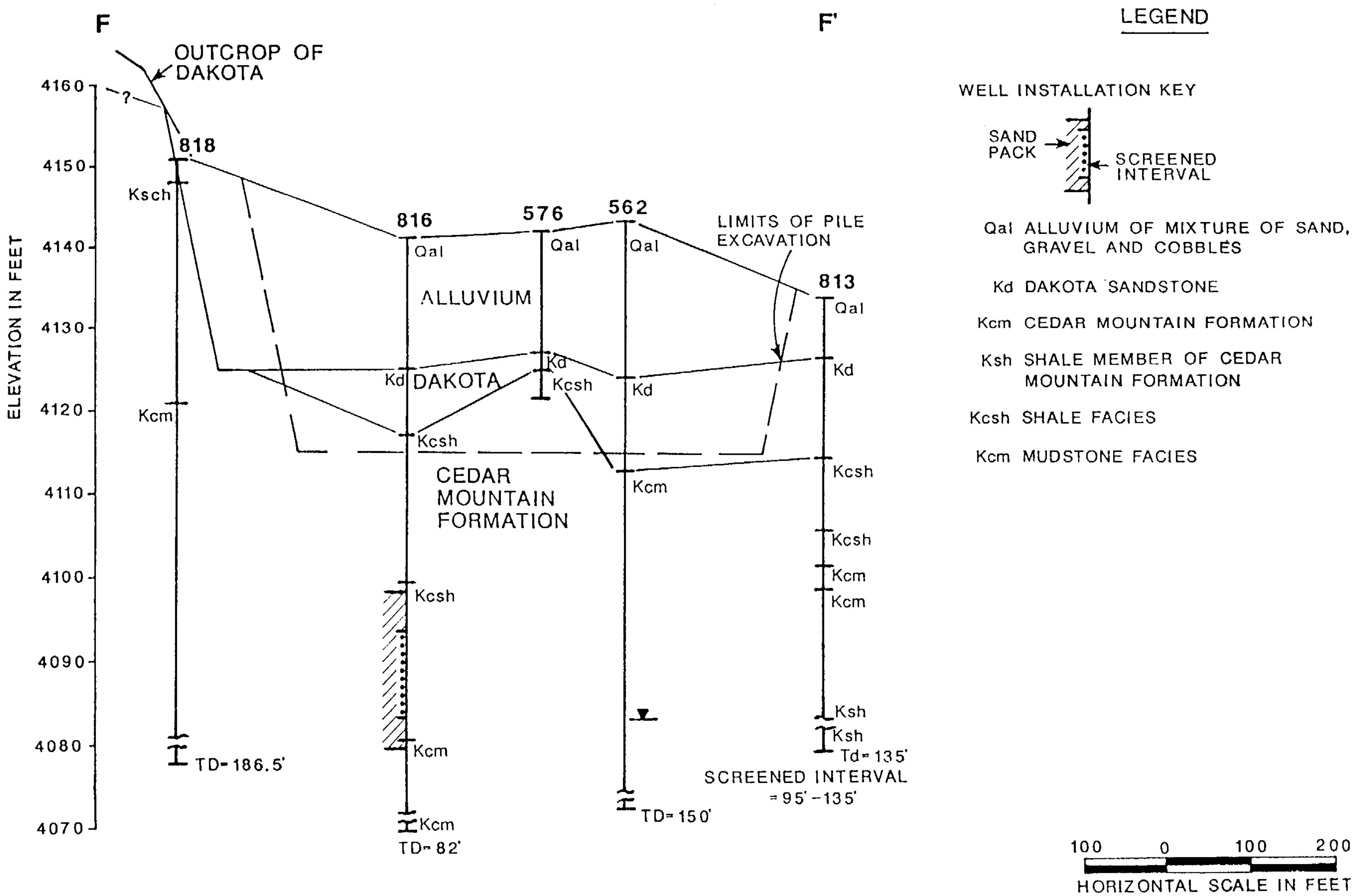


FIGURE 3.14
GREEN RIVER SITE CROSS SECTION F-F'

Groundwater was not encountered within the soils at the site. The first groundwater in this disposal area is within the Cedar Mountain Formation at approximately 55 feet below the ground surface. Section 3.5 describes the groundwater conditions within the bedrock.

3.4.3 Borrow sites

Radon cover and filter materials

Radon cover and gravel filter materials from borrow site 1 (Figure 3.15) were explored during an initial investigation by 14 test pits excavated with a backhoe. The locations of these test pits and cross sections are presented in Figure 3.16. Cross sections of the borrow sites were developed as shown in Figures 3.17 through 3.23. The test pits were logged and sampled by a field engineer. An additional 10 test pits were constructed by MKE during a final field investigation. The location of these are shown on Figure 3.24.

Borrow site stratigraphy

The near-surface soils at the site consist of zero to six feet of clayey to silty sands overlying clean sand and gravel or clay that is in turn underlain by gravel. The near-surface silty and clayey sands are not suitable for infiltration/radon barrier material. The clay layer, which is between four and more than eleven feet thick, is suitable for radon barrier material. This material is primarily in the northeast corner of the area originally explored. The final investigation indicates the clays become more extensive to the northeast. Groundwater was not encountered in the test pits.

Rock borrow materials

Rock of a quality to be considered suitable for use according to NUREG/CR-4620 will be used on the pile. The source is approximately 75 miles west of the site at Fremont Junction.

3.5 GROUNDWATER

Groundwater conditions and groundwater quality impacts resulting from the processing and disposal of uranium at the Green River tailings site are summarized in this section. A detailed discussion is provided in Section D.5, Groundwater Hydrology, of Appendix D. Appendix D also contains numerous tables and figures that are helpful in understanding groundwater conditions at the Green River tailings site.

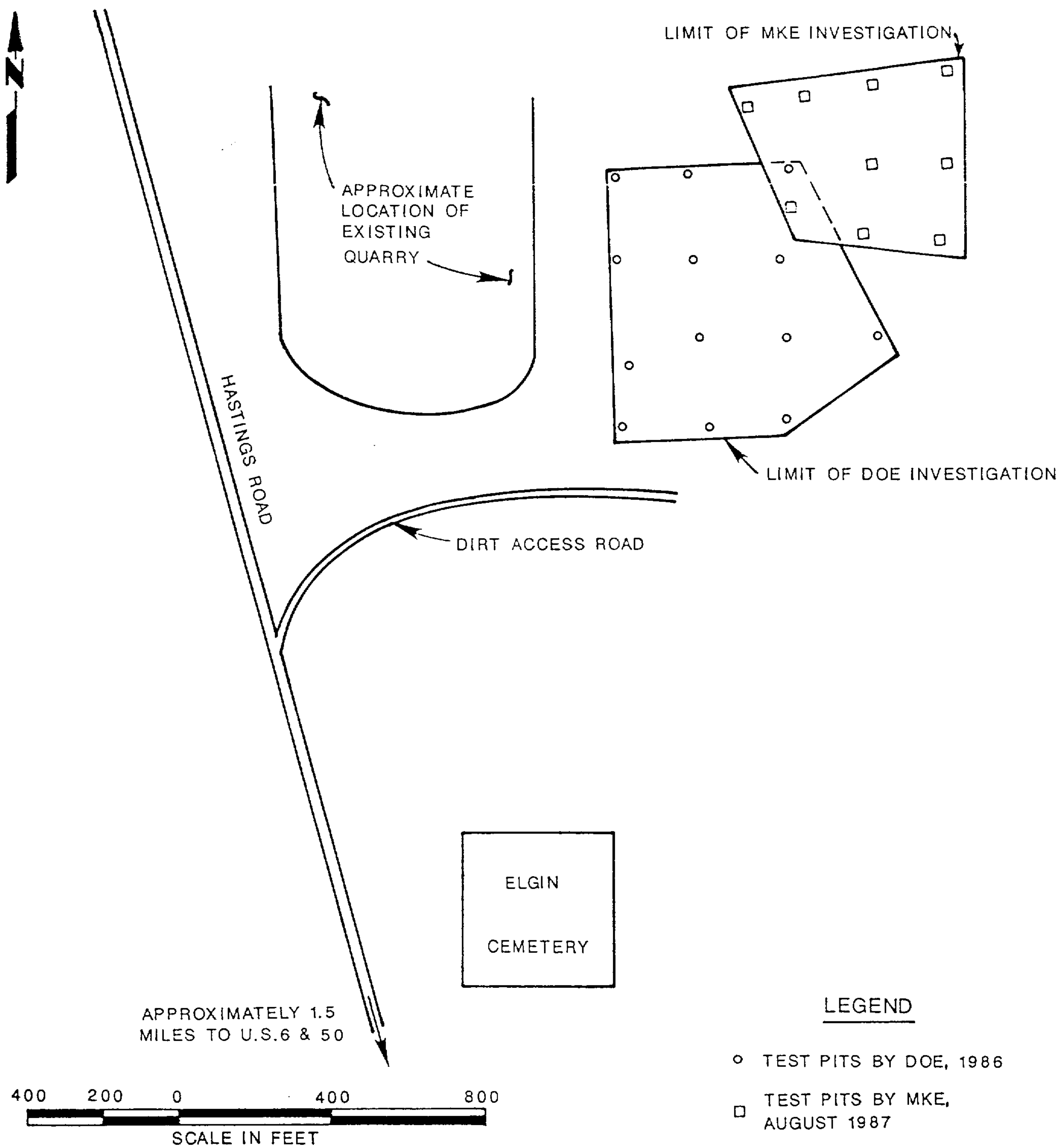


FIGURE 3.15
PROPOSED RADON BARRIER BORROW AREA AND VICINITY

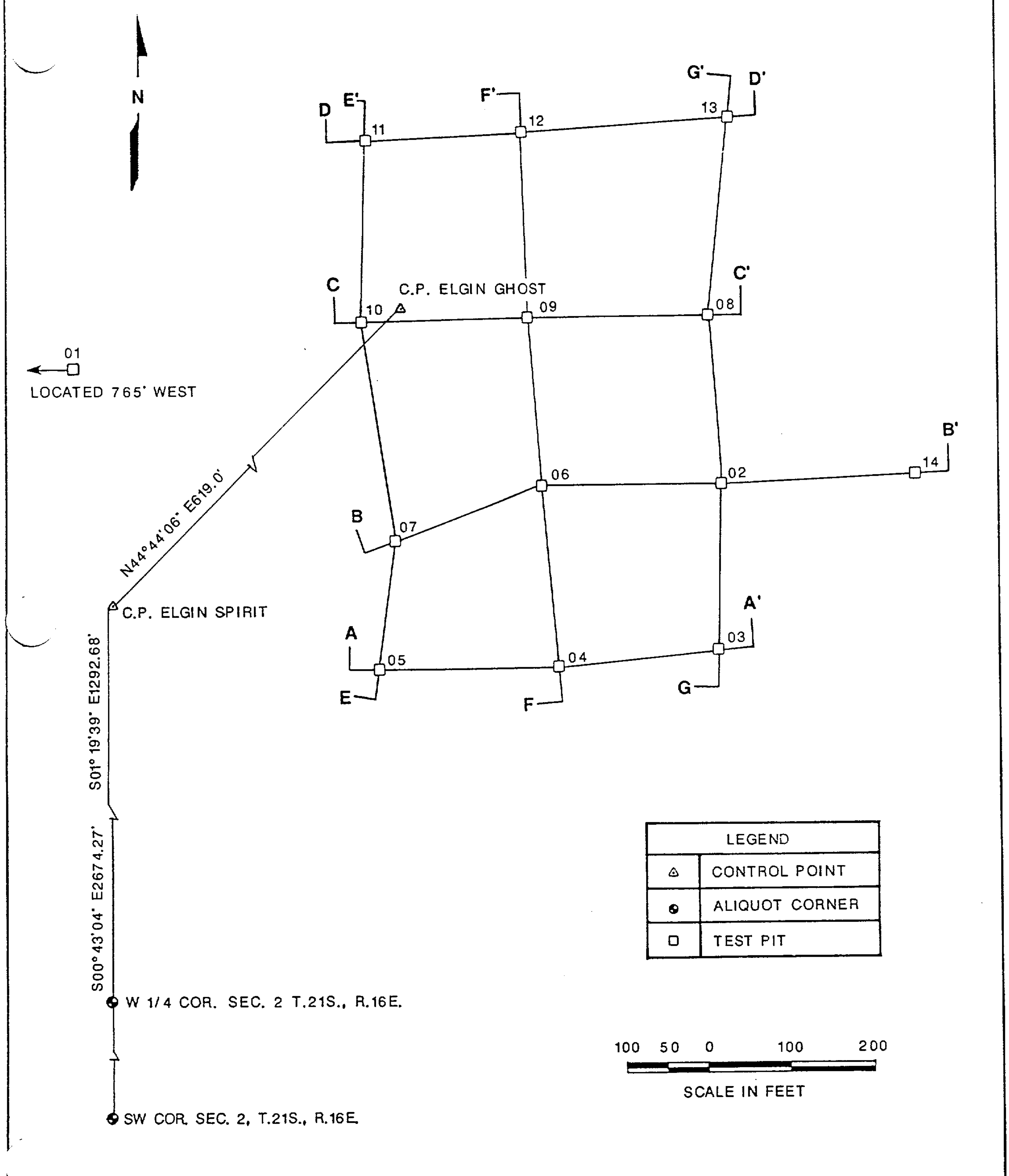


FIGURE 3.16
BORROW SITE 1 DOE TEST PIT LOCATIONS

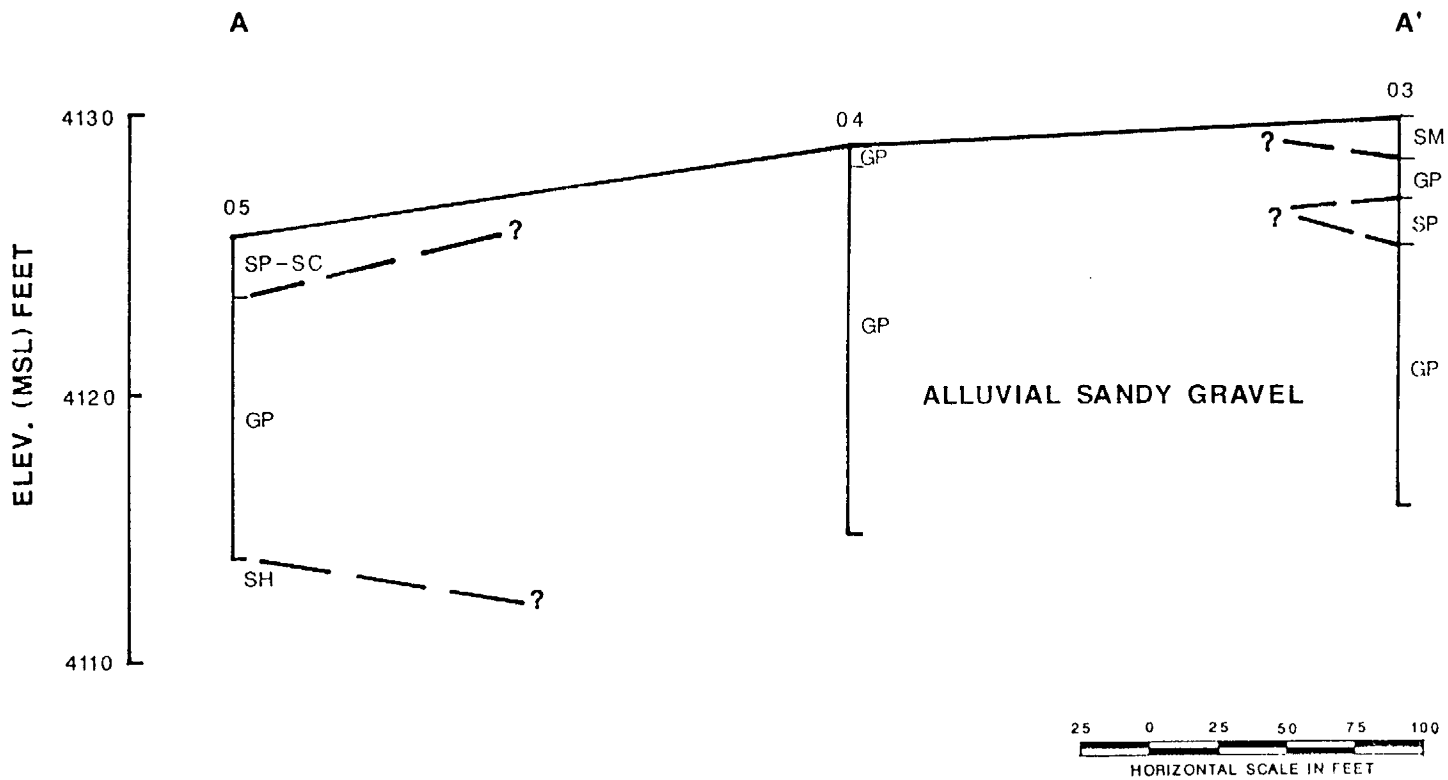


FIGURE 3.17 BORROW AREA 1 CROSS SECTION A-A'

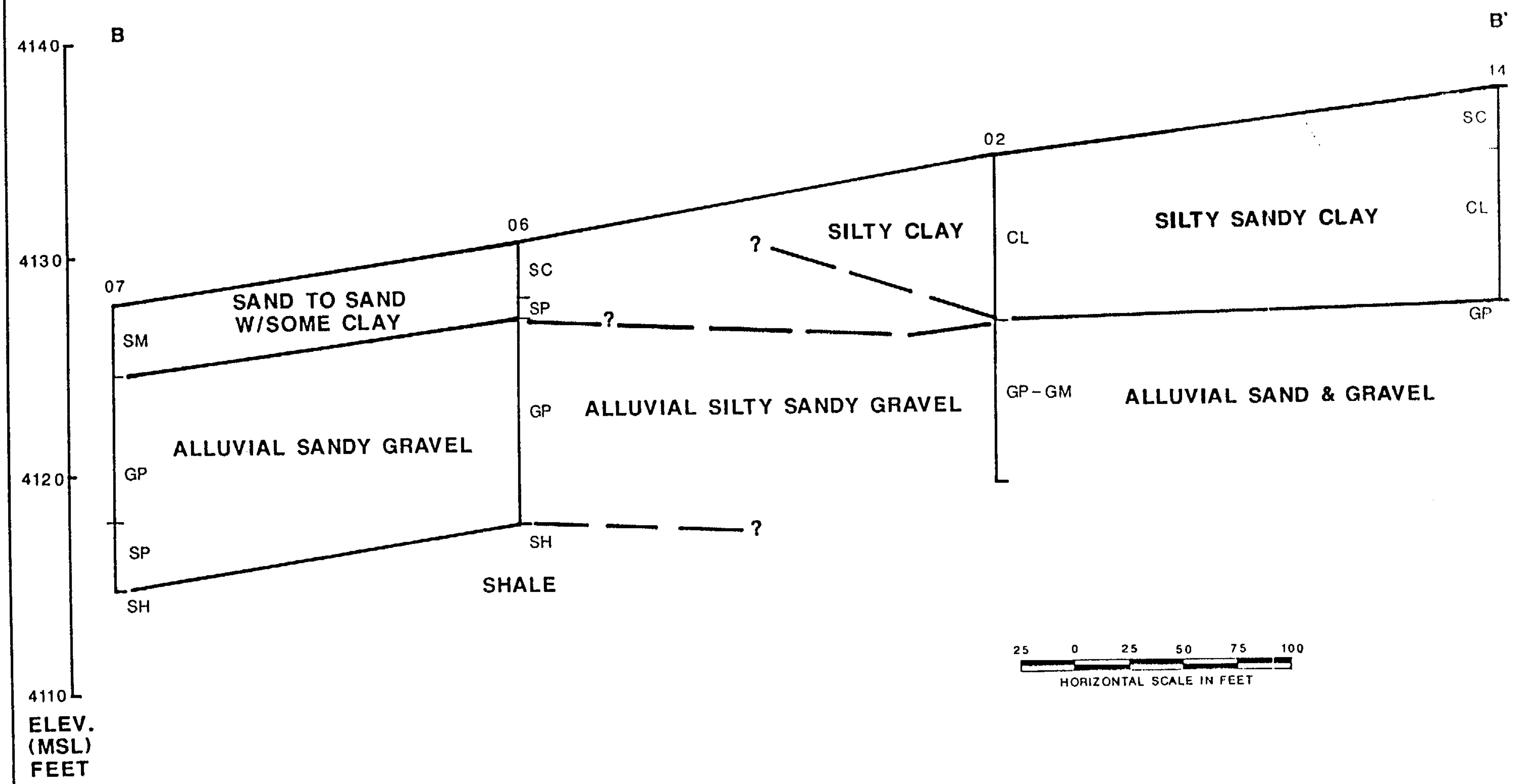


FIGURE 3.18 BORROW AREA 1 CROSS SECTION B-B'

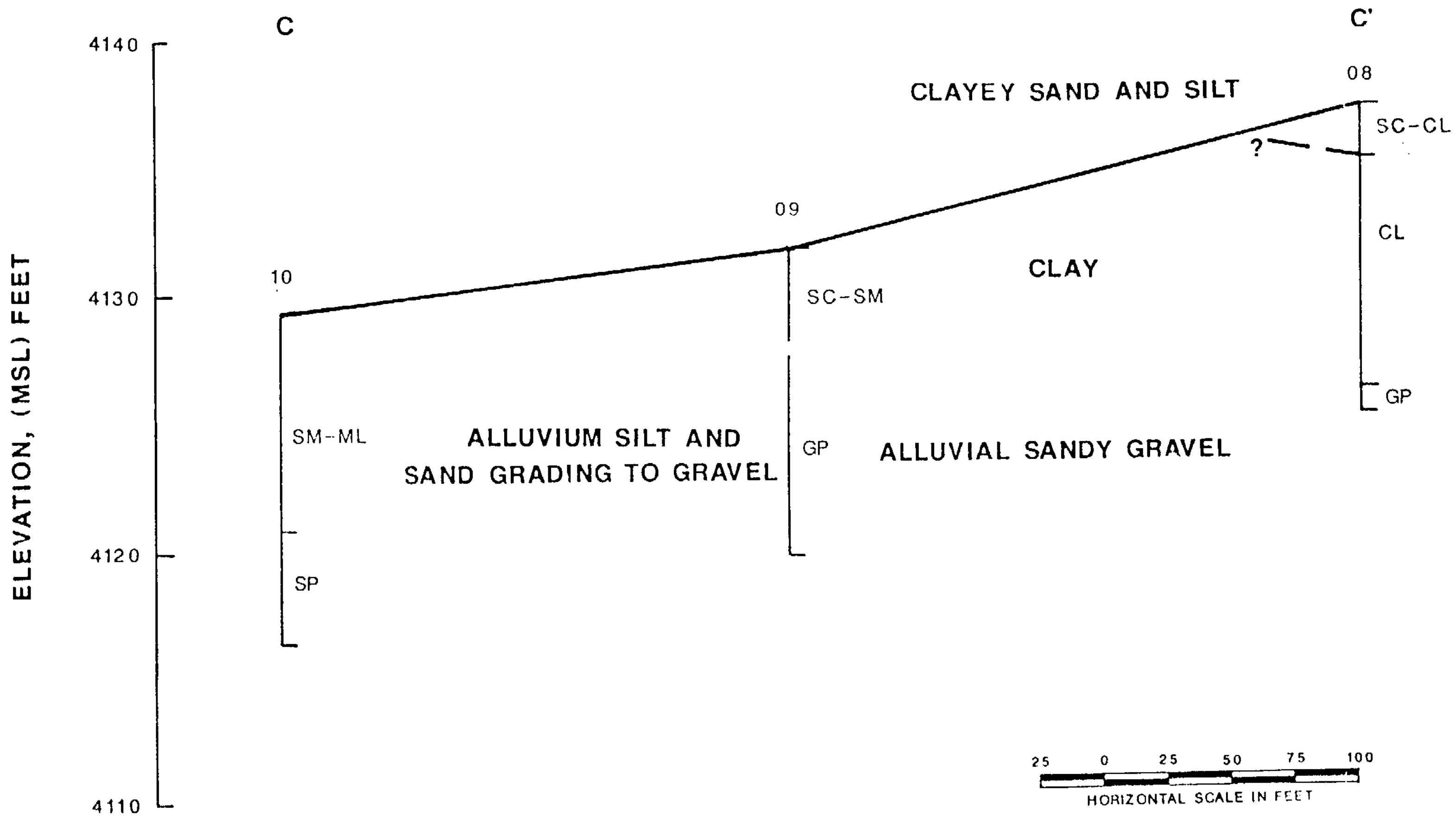


FIGURE 3.19 BORROW AREA 1 CROSS SECTION C-C'

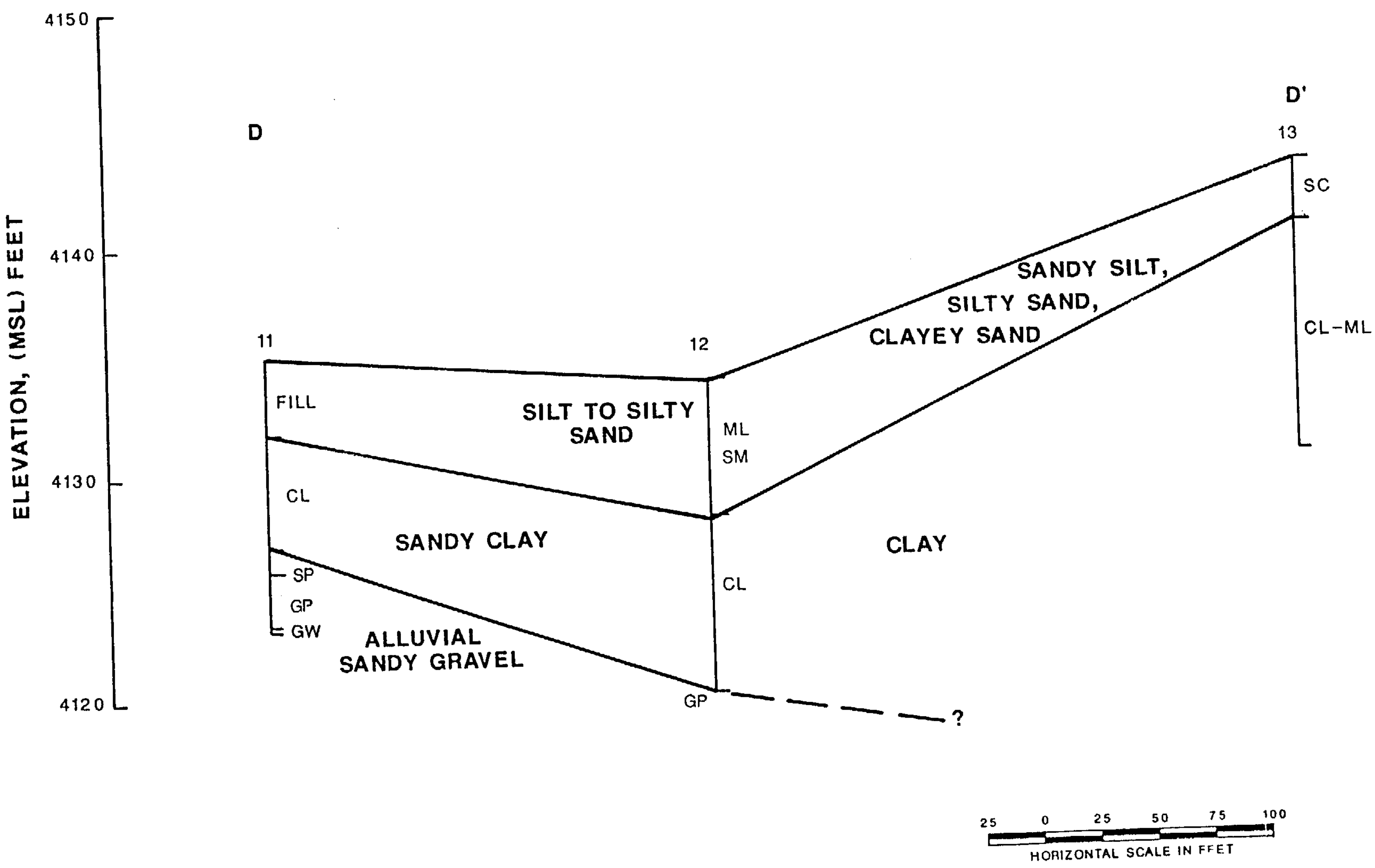


FIGURE 3.20 BORROW AREA 1 CROSS SECTION D-D'

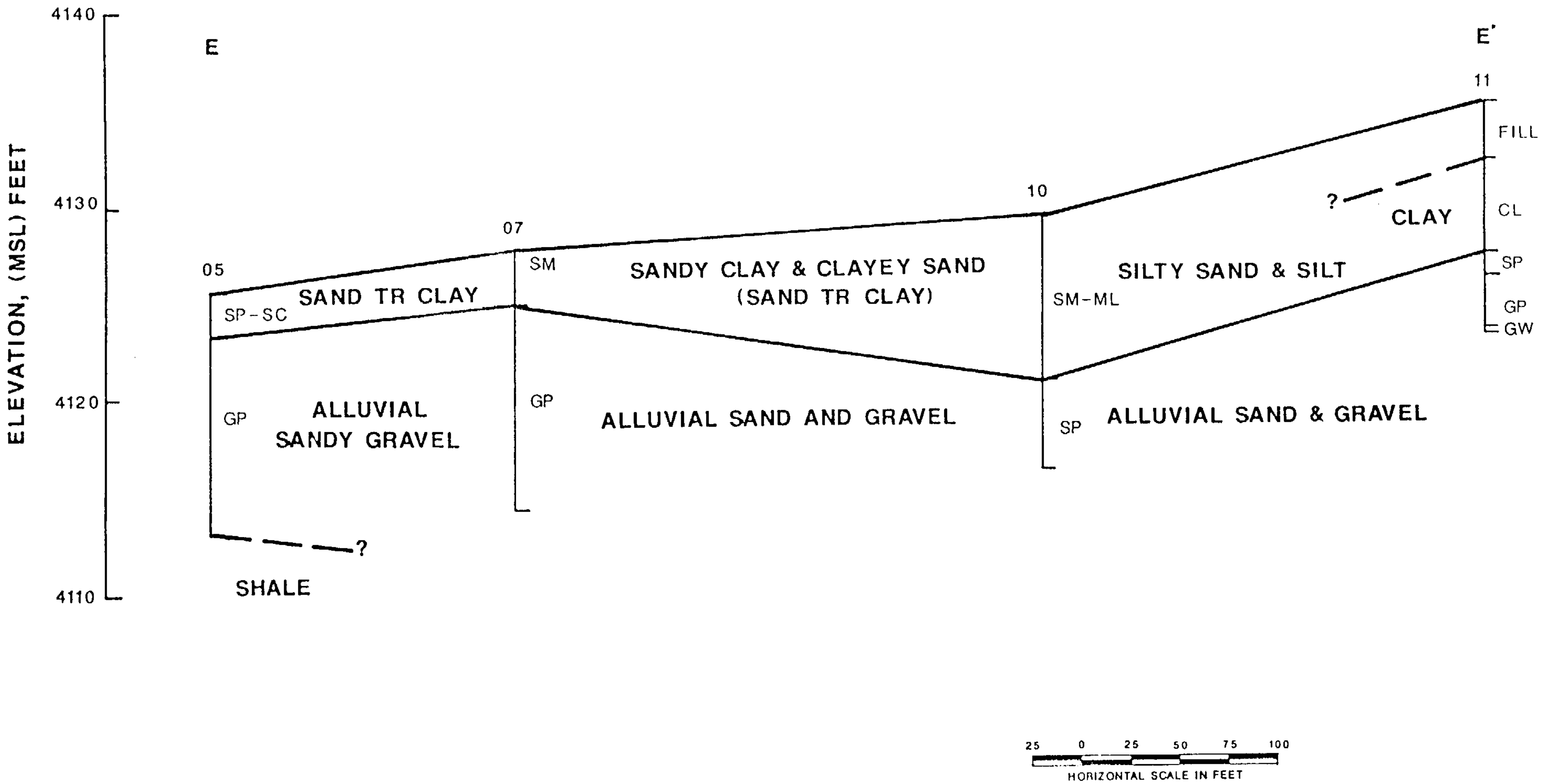


FIGURE 3.21 BORROW AREA 1 CROSS SECTION E-E'

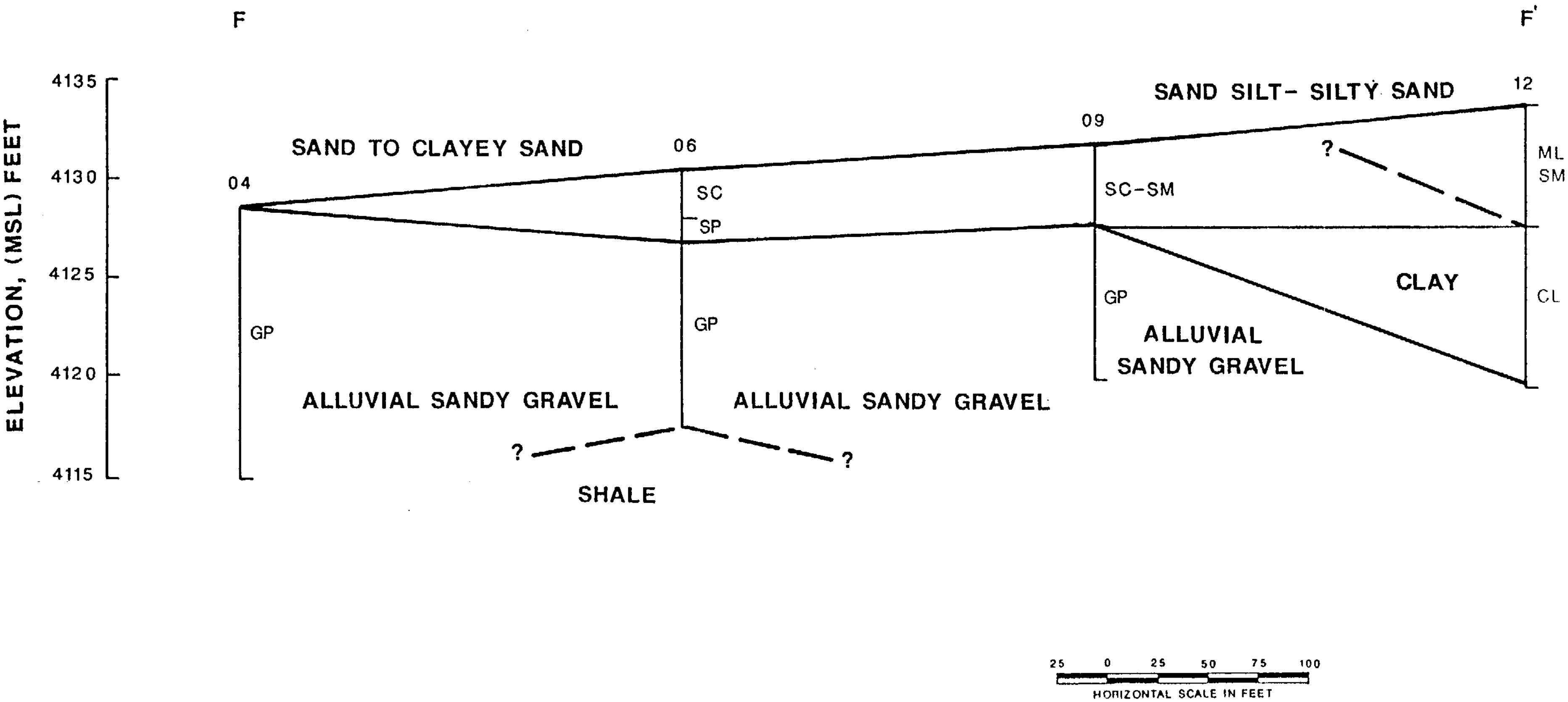


FIGURE 3.22 BORROW AREA 1 CROSS SECTION F-F'

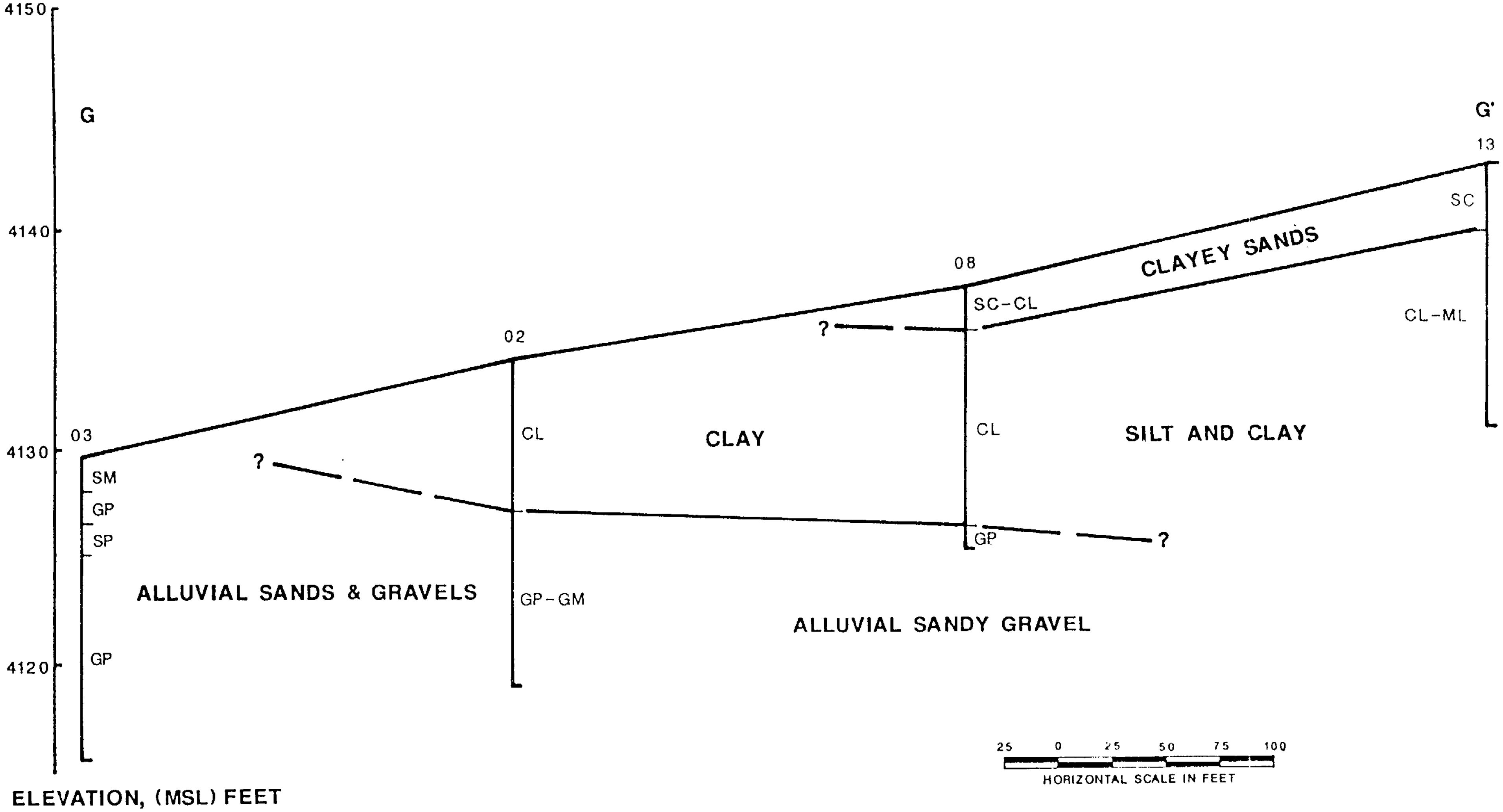


FIGURE 3.23 BORROW AREA 1 CROSS SECTION G-G'

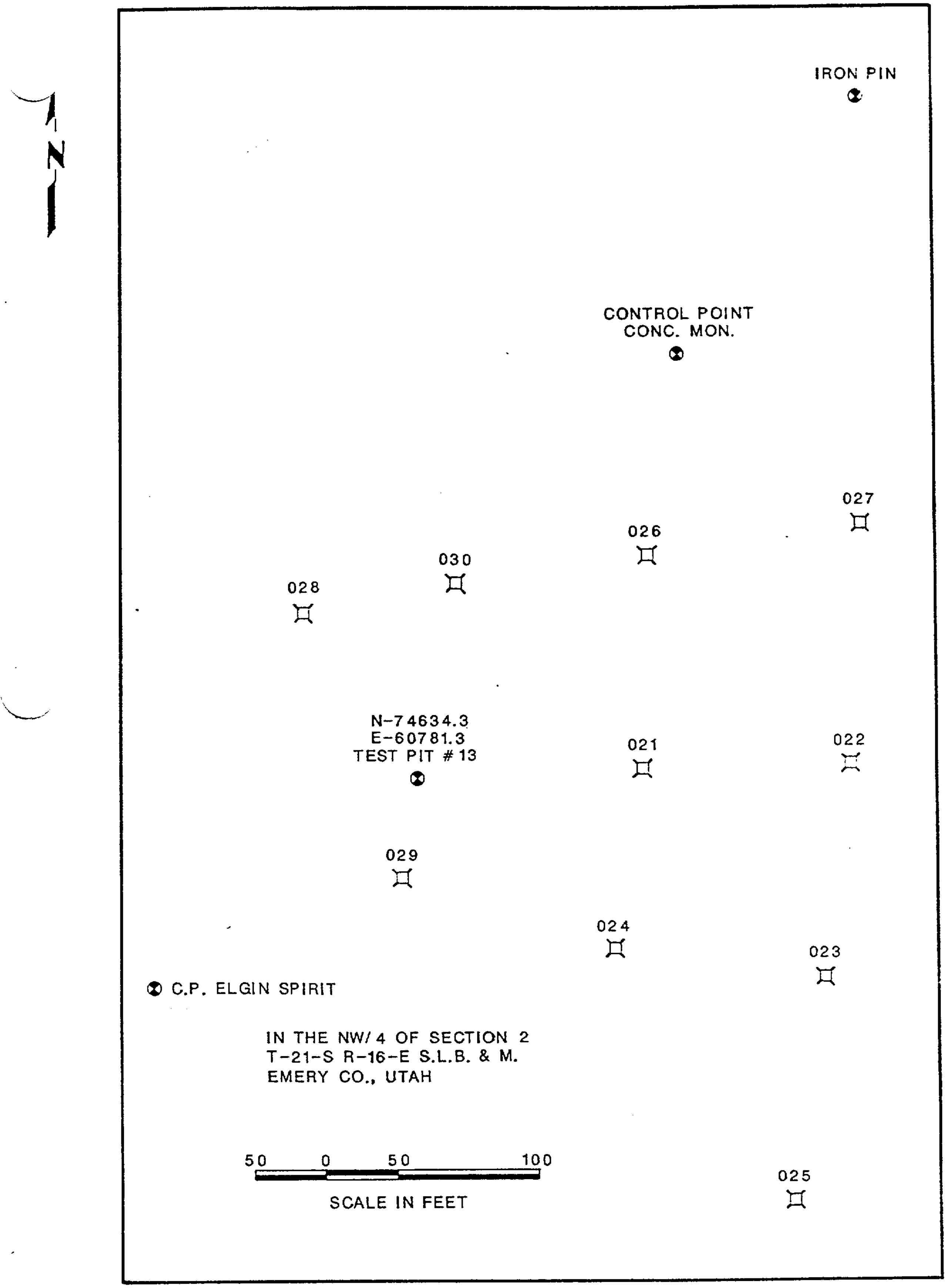


FIGURE 3.24
BORROW SITE 1 MKE TEST PIT LOCATIONS

3.5.1 Hydrostratigraphy

Within the upper 200 feet of Quaternary and Cretaceous sediments, four distinct water-bearing units were defined at the Green River tailings site. The following is a description of these four hydrostratigraphic units.

Top hydrostratigraphic unit

Shallow, unconfined groundwater occurs in the Brown's Wash alluvium beneath the present tailings pile; this alluvial aquifer is the top hydrostratigraphic unit. The alluvium consists of a mixture of silt, sand, gravel, and some small cobbles. The alluvium is limited to an area that extends 300 to 400 feet on either side of Brown's Wash, and varies in thickness from zero to 35 feet. The Brown's Wash alluvium is not present beneath the proposed disposal site.

Upper-middle hydrostratigraphic unit

Confined and unconfined groundwater occurs in the Cedar Mountain Formation beneath the present tailings and proposed disposal area. A sequence of alternating shales, limestones, and mudstones within the upper portion of the Cedar Mountain Formation is the upper-middle hydrostratigraphic unit. This unit is slightly to very fractured. The upper-middle unit is about 30 feet thick beneath the tailings and Brown's Wash alluvium, and 10 to 40 feet thick beneath the proposed disposal area. In some areas, the Dakota Sandstone lies unconformably on top of the upper-middle unit.

Lower-middle hydrostratigraphic unit

The lower-middle hydrostratigraphic unit is a relatively thick, but laterally limited, sandstone and sandstone conglomerate of the middle Cedar Mountain Formation. This unit is also slightly to very fractured, and is beneath the present tailings and the proposed disposal site. East and west of the site area, the lower-middle unit intertongues with the shales and limestones of the upper-middle hydrostratigraphic unit, and the lower-middle unit becomes thin and discontinuous. The lower-middle unit is 20 to 30 feet thick beneath the tailings and proposed disposal site, and is nonexistent in some areas west of the site area.

Bottom hydrostratigraphic unit

The bottom hydrostratigraphic unit is the Buckhorn Conglomerate member of the lower Cedar Mountain Formation. This basal sandstone and sandstone conglomerate unit is 15 to 25 feet thick beneath the site area and is confined by overlying shale and mudstone. This unit is slightly fractured to unfractured. Jurrasic-age sedimentary rocks lie beneath the bottom hydrostratigraphic unit.

3.5.2 Groundwater movement

The presence and movement of shallow groundwater beneath the tailings site is controlled by extensive fracturing of the bedrock; strong, vertically upward hydraulic gradients and movement of groundwater upward between bedrock units; and the attitude (dip) of the bedrock units. Flow of groundwater in the Brown's Wash alluvium is controlled by recharge from the east (upstream); recharge from the upper-middle shale unit south of Brown's Wash; discharge of groundwater into the upper-middle shale unit west (downgradient) of the tailings; and discharge of groundwater into the channel of Brown's Wash at the surface. The occurrence of groundwater in Brown's Wash is also limited by the lateral extent of the alluvium; the top hydrostratigraphic unit is a maximum of 600 feet wide near the tailings pile. The following describes the flow of groundwater beneath the tailings site in more detail.

Top hydrostratigraphic unit

The depth to groundwater ranges from nine to 17 feet below the surface in the top unit. The general direction of groundwater flow in this unit is west toward the Green River; however, the flow is locally controlled south of Brown's Wash channel (beneath the present tailings pile) by recharge from the underlying upper-middle unit. Beneath the tailings, groundwater in the alluvium flows northwest at a volume rate of about 9.9 gallons per minute (gpm); the velocity of flow ranges between 0.55 and 2.19 feet per day (ft/day). West of the tailings, groundwater flowing in the top unit is divided into three major components: (1) surface water flow and subflow in Brown's Wash channel; (2) evaporation and transpiration, primarily near Brown's Wash channel; and (3) discharge down into the underlying upper-middle hydrostratigraphic unit (or through the Dakota Sandstone, where it is present), primarily via vertical fractures in the bedrock. Since two well points and one monitor well completed in the top unit immediately west of the tailings pile have been dry during the sampling period (June 1986 through October 1987), it is estimated that very little groundwater that originates from beneath the tailings pile flows in the top unit much further than 400 feet west (downgradient) from the tailings.

Upper-middle hydrostratigraphic unit

The depth to groundwater in the upper-middle unit beneath the present tailings surface is about 26 feet. The general direction of groundwater flow in this unit is west toward the Green River.

However, like the top hydrostratigraphic unit, the flow of groundwater in the upper-middle unit is also locally controlled by recharge from south of the tailings pile by flow from underlying units. Beneath the tailings pile the potentiometric surface of the upper-middle unit forms a "trough" or groundwater sink, indicating that the flow of groundwater along the sink is controlled by a zone of higher secondary permeability, likely from jointing, fracturing, or minor faulting of the bedrock. It is along this sink that the upper-middle unit is recharged by groundwater from the overlying Brown's Wash alluvium (top unit). Beneath the tailings, groundwater flows in the upper-middle hydrostratigraphic unit at a volume flow rate of about 4.9 gpm; the velocity of flow ranges from 0.01 to 0.71 ft/day.

Groundwater in the upper-middle unit beneath the proposed disposal site is first encountered at a depth of about 60 feet (groundwater is not present beneath the disposal site above this depth). Beneath the southern one-third to one-half of the proposed disposal area, the upper-middle unit is dry or is only saturated in the bottom one to two feet. North of the disposal site, the upper-middle unit becomes saturated as the bedrock units dip toward the north. Between the disposal site and the present tailings pile, the flow of groundwater in the upper-middle unit is controlled by connected fractures, recharge from south of the disposal area or from underlying aquifers, and by the dip of the bedrock units. The flow of groundwater in the upper-middle unit beneath the disposal site is about two gpm.

Lower-middle hydrostratigraphic unit

The depth to the top of the lower-middle unit beneath the tailings surface is 60 to 65 feet. However, the potentiometric surface of the lower-middle unit is two to three feet above the surface of the tailings. A strong, vertically upward hydraulilc gradient exists between the lower-middle unit, and the overlying top- and upper-middle hydrostratigraphic units, which has prevented seepage and contaminants from the tailings from entering the lower-middle unit. The general direction of groundwater flow in the lower-middle unit beneath the tailings pile is west toward the Green River. West and east of the tailings, the lower-middle unit intertongues with the upper-middle unit, and the lower-middle unit becomes thin and discontinuous or nonexistent in some places. The flow of groundwater in the lower-middle unit west and east of the tailings is undoubtedly controlled by the intertonguing. The volume flow rate of groundwater in the lower-middle unit beneath the present tailings pile was not calculated since this unit has not been affected by tailings seepage.

Groundwater in the lower-middle unit beneath the proposed disposal site is first encountered at a depth of about 60 feet. Groundwater flow in this unit between the disposal site and the present tailings pile is controlled by the same factors that control flow in the overlying upper-middle unit. The flow of groundwater in the lower-middle unit beneath the disposal site is about two gpm.

Bottom hydrostratigraphic unit

Confined groundwater is present in the bottom unit beneath the tailings site. The potentiometric surface in the bottom unit is five to 14 feet above the present tailings surface, and 56 to 71 feet below the surface of the proposed disposal site. The direction of groundwater flow is north-northwest in the bottom unit. Groundwater flow through the bottom unit beneath the present tailings pile was not calculated since the bottom unit has not been affected (and will not be affected) by tailings seepage.

3.5.3 Groundwater quality

Groundwater quality at the Green River tailings site was characterized and compared with the proposed EPA standards for remedial action at inactive uranium processing sites and state of Utah drinking water standards. Since the maximum concentration limits for the proposed EPA standards and the Utah Primary Drinking Water Standards are the same, the ensuing discussion will refer only to the EPA standards. A list of standards for purposes of site characterization is provided in Table D.5.1 of Appendix D.

Background groundwater quality in the four hydrostratigraphic units at the Green River site was determined for the following proposed EPA constituents: chromium; molybdenum; nitrate; selenium; radium-226 and 228; uranium; and gross alpha. The other proposed EPA constituents listed in Table D.5.1 of Appendix D were found at levels below or near detection for the first two rounds of sampling in June 1986 and September 1986; consequently, some of these remaining constituents were excluded from subsequent sampling rounds and are not considered to be present as contamination at the Green River tailings site. Background groundwater quality in all four units is characterized by total dissolved solids (TDS) and concentrations of sulfate and chloride that exceed EPA and State of Utah Secondary Drinking Water Standards. Based on production capacity and TDS, groundwater in all four units would be classified as Class II. However, it may be classified as Class III because of the presence of selenium, molybdenum, chromium, nitrate, and uranium in background samples that exceeds proposed EPA maximum concentration limits for those constituents. A Class III designation of the groundwater at the Green River site based upon these criteria is not pursued in this RAP, and is not a component of the water resource protection strategy for disposal of tailings at the Green River site. However, the poor background and baseline water quality of the uppermost aquifer will be reconsidered when Subpart C (groundwater restoration) of the standard is pursued in a separate process.

Background groundwater quality in the top hydrostratigraphic unit is characterized by maximum concentrations of chromium (0.14 milligrams per liter, or mg/l), molybdenum (0.20 mg/l), nitrate (140 mg/l), and selenium (0.38 mg/l), and gross alpha activity (41 pCi/l) that exceed proposed EPA maximum concentration limits for these constituents. In the upper-middle unit, maximum concentrations of nitrate (93 mg/l), selenium (2.50 mg/l), and gross alpha activity (21 pCi/l) exceed proposed EPA maximum concentration limits; uranium (0.038 mg/l) is very close to the proposed maximum concentration limit of 0.044 mg/l. Background groundwater quality in the lower-middle hydrostratigraphic unit is characterized by concentrations of chromium (0.09 mg/l), molybdenum (0.22 mg/l), nitrate (173 mg/l), selenium (0.32 mg/l), uranium (0.155 mg/l), and gross alpha activity (150 pCi/l) that exceeds the proposed EPA maximum concentration limits for these constituents. In the bottom hydrostratigraphic unit, background concentrations of chromium (0.07 mg/l), molybdenum (0.14 mg/l), selenium (0.106 mg/l), and gross alpha activity (30 pCi/l), exceed proposed EPA maximum concentration limits.

Contaminated groundwater upgradient of the present tailings pile was also detected in the shale and mudstone of the Cedar Mountain Formation beneath the lower-middle unit. This contaminated water was collected from a monitor well located south (upgradient) of the tailings and west of the proposed disposal site. Maximum concentrations of nitrate (1280 mg/l) and selenium (0.322 mg/l) are over one order of magnitude higher than the proposed EPA maximum concentration limits for these constituents; the boron concentration is 0.84 mg/l, which is slightly higher than the State of Utah Drinking Water Standards maximum concentration limit of 0.75 mg/l. Since this saturated zone within the Cedar Mountain Formation (78 to 98 feet below the surface) is isolated from any surface source of contamination by strong, vertically upward hydraulic gradients, the source for contaminants found within this unit is from somewhere off of the tailings site, and possibly from an elevation below (upgradient of) the contamination.

The percolation of tailings leachate into the groundwater system beneath the present tailings pile has adversely impacted the water quality in both the top and upper middle hydrostratigraphic units. The vertical extent of the contamination is confined to these two units by strong, vertically upward hydraulic gradients between the upper-middle unit and the underlying units. The maximum depth of contamination beneath the surface of the tailings is about 65 feet. Groundwater within the top and upper-middle units beneath the tailings contains levels of gross alpha activity, molybdenum, nitrate, selenium, and uranium that exceed the proposed EPA standards and/or background levels for these constituents; ammonium levels also exceed background levels (ammonium has neither a proposed EPA standard nor a Utah drinking water standard). The maximum concentrations observed for these contaminants in the top unit are: gross alpha activity (950 pCi/l); molybdenum (0.27 mg/l); nitrate (440 mg/l); selenium (0.41 mg/l); uranium (2.23 mg/l); and ammonium (42 mg/l). In the upper-middle unit, the observed maximum concentrations are: gross alpha activity (980 pCi/l); molybdenum (0.20 mg/l); nitrate (2480 mg/l); selenium (0.37 mg/l); uranium (3.11 mg/l); and ammonium (47 mg/l).

The contamination resulting from the tailings seepage travels downgradient through the top unit (Brown's Wash alluvium) toward the northwest and the channel of Brown's Wash. Once in Brown's Wash the contaminants move west with groundwater flow in the shallow alluvium (as subflow in the channel) or on the surface.

Surface water sample analyses from Brown's Wash (DOE, 1988a) indicate contaminated groundwater discharges to Brown's Wash; however, flow in the channel is intermittent and the concentrations of the contaminants (as well as major cations and anions) are a function of the evaporation of water in the channel (i.e., evaporation causes a relative increase in concentration of the contaminants). The contaminated water travels downstream (west) in Brown's Wash and mixes with backwater from the Green River. Water quality analyses from samples of Green River water upstream and downstream from its confluence with Brown's Wash show that the discharge of contaminated water from Brown's Wash to the Green River has no adverse affect on the water quality of the Green River (DOE, 1988a). This is because the contaminants are diluted by a factor of 10^5 to 10^6 once they mix with the Green River.

Contamination from tailings leachate in the upper-middle hydrostratigraphic unit extends northwest from the tailings pile. Contaminant plumes of gross alpha, molybdenum, and nitrate extend 1000 to 1200 feet downgradient of the middle portion of the tailings pile. Selenium, which seems to be the most mobile of the contaminants, extends 1800 feet or more downgradient of the tailings. Uranium has probably moved only 300 to 600 feet downgradient of the middle portion of the tailings pile, and the plume probably does not extend past the west (downgradient) edge of the pile; this indicates that uranium is being geochemically attenuated in the upper-middle unit. Contamination is also present near Brown's Wash in the upper-middle unit 1500 to 1600 feet west of the tailings. The source of this contamination is likely seepage of contaminated water in Brown's Wash channel into the bedrock channel bottom, primarily through connected vertical fractures in the bedrock. Since the source concentrations of the contaminants at this location are far less than the concentrations at the tailings source, this "secondary" plume of contamination is very localized and probably does not extend very far beyond the channel of Brown's Wash.

3.5.4 Groundwater use, value, and alternative supplies

There are 15 registered wells in Township 21 South, Range 16 East in the Green River area. Only one of these wells is on the same side of the Green River as the tailings site, and none are within the potentially affected environment of the tailings site. The majority of the 15 registered wells are not being used because of poor quality of the water, disrepair of the wells, and the availability of better quality water from the city of Green River. The usage of groundwater in the vicinity of Green River is consistent with the usage of groundwater on a regional basis. It is difficult to assign a value to groundwater that has no use or only very limited use. Qualitatively, it can be stated that the shallow groundwater, either affected or unaffected by tailings seepage, has little or no value because of the naturally high concentrations of selenium, molybdenum, chromium, nitrate, and uranium found within it. For this reason, the shallow groundwater may be classified as Class III (i.e., the groundwater is contaminated naturally to the extent that it cannot be cleaned up using treatment methods reasonably employed in public water supply systems).

Future use of shallow groundwater for domestic consumption in the site area is not expected due to its poor natural quality and the availability of better quality water from the Green River. In spite of the poor natural quality of the groundwater within the Brown's Wash alluvium (top hydrostratigraphic unit) and the upper and lower portions of the Cedar Mountain Formation, water suitable for livestock and some crop irrigation was located in the Buckhorn Conglomerate Member of the Cedar Mountain Formation beneath the tailings site; this unit is protected from current and future contamination in the overlying aquifers by strong, vertically upward hydraulic gradients.

The seepage of tailings fluids from the Green River site has not adversely impacted any groundwater currently being used. Alternate water supplies to residents in the Green River area include Green River water as currently supplied by the city of Green River, and commercial (bottled) water.

3.6 SURFACE WATER

The tailings pile and mill site at the Green River site are on a slope between an upper abandoned river terrace and the southern edge of the present floodplains of the Green River and Brown's Wash.

Major tributaries of the Green River (which joins the Colorado River 100 miles downstream of the site) are the Yampa and White Rivers of Colorado and the Duchesne and Price Rivers of Utah, all of which flow into the Green River above the site, and the San Rafael River, which joins the Green River about 20 miles downstream of the site. Brown's Wash has a drainage area of approximately 85 square miles near the Green River tailings site. Approximately 750 feet northeast of the tailings pile an unnamed intermittent stream flows into Brown's Wash.

Surface runoff north of the site is diverted from Brown's Wash and the tailings site by a railroad embankment. Runoff from the mill site is directed northwest to Brown's Wash and eventually to the Green River. An area of approximately 110 acres drains to the disposal area southeast of the mill yard. This area is drained to the southwest and northeast by several small gullies.

The tailings pile is subject to erosion and inundation from flood events in Brown's Wash having a recurrence interval of approximately 500 years. Floods with lesser recurrence intervals could cause erosion of the tailings due to bank failure. The tailings pile would not be affected by flooding of the Green River because the overbank areas are broad and flat and flow could not reach the pile. The proposed disposal area is not susceptible to flooding of either the Green River or Brown's Wash.

There are no uses of water in Brown's Wash in the vicinity of the Green River site. The city of Green River presently takes water out of the Green River upstream of the confluence with Brown's Wash for municipal use. Withdrawal downstream of the site is minimal.

The quality of water in Brown's Wash is affected by the presence of the tailings. The effect is dependent on the quantity of flow in the wash. There are no measurable effects from the tailings on the quality of water in the Green River.

4.0 SITE DESIGN

4.1 INTRODUCTION

This section discusses the following design items for remedial action at the Green River, Utah, UMTRA site:

- o Remedial action objectives.
- o Permanent design features.
- o Construction features.
- o Construction activities and schedule.

Maps, drawings, and tables relevant to the design are provided in this section and the appendices of this RAP. The site design presented herein is described to demonstrate compliance with EPA standards.

The main objectives of the site design are to satisfy the UMTRCA and the EPA standards restricting the release of contaminated materials into the environment and limiting the release of radon gas and gamma radiation from tailings, contaminated soils, and other contaminated materials.

4.2 DESIGN OBJECTIVES

The major design objectives are as follows:

- o Consolidate and stabilize contaminated materials in a disposal embankment above the elevation of the Probable Maximum Flood (PMF) in Brown's Wash.

- o Reduce radon flux to the atmosphere from tailings and from other contaminated materials to levels not greater than 20 pCi/m^2s.

- o Design permanent features for stabilization of tailings and other contaminated materials to be effective for at least 1000 years to the extent achievable, and in any event, for at least 200 years.

- o Prevent human and animal disturbance of the disposal embankment.

- o Minimize, to the extent achievable, the impact of materials in the disposal embankment on ground and surface water.

- o In areas that will be released for unrestricted use, reduce Ra-226 contamination levels to less than five pCi/g above background levels in the top 15 cm of soil and to less than 15 pCi/g above background levels in any 15-cm-thick soil layer beneath the top 15 cm.

- o Minimize the size of the restricted final disposal site.

- o Minimize the release of contaminants from the site during construction.

- Minimize the area disturbed during construction.

- Minimize the exposure of workers and the general population to contaminated materials.

4.3 DESIGN SUMMARY

4.3.1 Remedial action summary

The main feature of the remedial action is relocation and stabilization of contaminated materials in a disposal embankment on a terrace located above Brown's Wash. Contaminated materials to be relocated will include:

- Materials from the tailings pile.

- Windblown contamination on the surface of the site and adjacent areas and contaminated materials from vicinity properties.

- Debris resulting from demolition of contaminated buildings.

- Contamination resulting from decontamination of buildings.

The disposal embankment will cover six acres and contain 339,377 in-place cubic yards of contaminated materials.

The mill site is located approximately one-half mile east of the Green River and one mile southeast of the city of Green River. The disposal embankment will be located southeast of the former mill site on a terrace 70 feet above the elevation of the floodplain of Brown's Wash. The location and design of the disposal embankment have been selected to protect against erosion from Brown's Wash and against undercutting of the embankment by gully formation.

The stabilized embankment will be constructed primarily below the existing ground surface. The excavation for the below-grade portion of the embankment will extend into bedrock of the Dakota and Cedar Mountain Formations. Excavation will be performed with conventional earth-moving equipment. Tailings and windblown contaminated material will be placed and compacted in horizontal layers starting on top of a six-foot-thick layer of compacted select soil fill placed at the bottom of the excavation.

An infiltration/radon barrier will be constructed of compacted uncontaminated materials. The infiltration/radon barrier is designed to protect groundwater by minimizing infiltration and to reduce radon flux from the embankment to less than 20 pCi/m^2s. The infiltration/radon barrier will consist of a 36-inch-thick layer of compacted silty clay imported from a source located 2.5

miles north of the site. Six percent bentonite by weight will be mixed into the radon barrier material to ensure a compacted infiltration/radon barrier saturated hydraulic conductivity of less than 2 x 10^{-8} cm/s.

An erosion protection layer will be constructed to protect the infiltration/radon barrier and embankment from runoff that would result from a Probable Maximum Precipitation (PMP) on the embankment and from runoff that would result from a PMF from the small watershed upslope of the embankment. The erosion protection layer is also designed to protect the embankment from the encroachment of gullies.

The uppermost portion of the erosion protection will be a layer of riprap. Above finished grade, the riprap will be 12 inches thick and have a minimum mean size of D_{50} = 2.6 inches. This riprap is referred to as Type A riprap. A six-inch-thick bedding layer will be placed above the select fill to prevent migration of the infiltration/radon barrier into the riprap. The lower 15 inches of the infiltration/radon barrier will be below the maximum projected frost depth at the toe of the sideslopes.

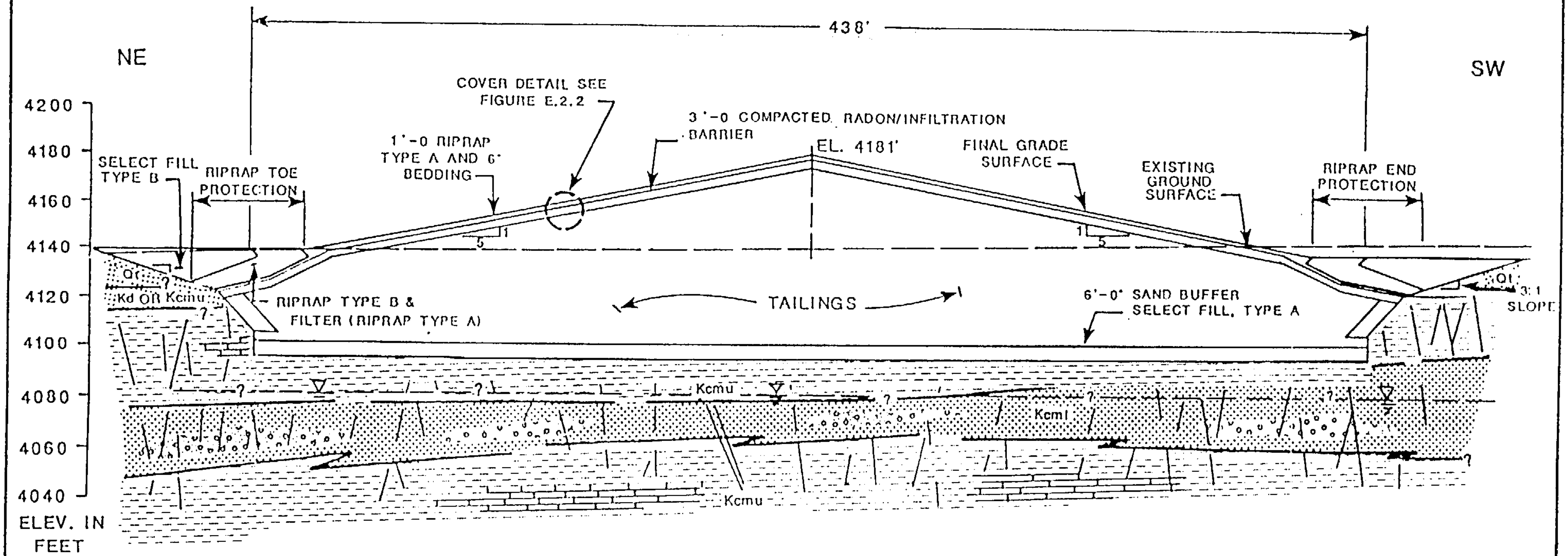
Below finished grade, the riprap will be a minimum of 36 inches thick and have a minimum D_{50} = 18 inches. This riprap is referred to as Type B riprap. A 12-inch-thick layer of Type A riprap and a six-inch layer of bedding material will be constructed between the infiltration/radon barrier and the Type B riprap. These intermediary layers will prevent migration of the infiltration/radon barrier into the Type B riprap.

The configuration of the infiltration/radon barrier, bedding, and Type A and B riprap layers are presented in Figures 4.1 and 4.2.

Slopes of the disposal embankment will be 5:1 and will be from the approximate bedrock surface elevation up to 4181 ft above mean sea level (MSL) at the top of the embankment.

Existing gullies near the disposal embankment will be regraded to minimize potential hazards of enlargement of the gullies and the formation of new gullies. Gravel fill materials will be placed and compacted in the bottom of each gully. The remainder of each gully will be filled with material from the disposal embankment excavation. About 69,900 cy of gravel will be used to fill gullies.

The mill building addition, the office building addition, and the roaster building will be demolished. Debris resulting from demolition will be buried in the disposal embankment. All demolition activities will be controlled to protect workers and to restrict release of airborne contamination. Contaminated material will not be removed from the site.



20 0 20 60

HORIZONTAL SCALE IN FEET

NOTE: SEE APPENDIX F FOR DETAILED PLANS AND SPECIFICATIONS

LEGEND

FORMATION		MATERIAL	SYMBOL
Qt	TERRACE SEDIMENTS	SOILS	
Kd	DAKOTA SANDSTONE	BEDROCK	SANDSTONE OR SILTSTONE
Kcmu	CEDAR MOUNTAIN FORMATION UPPER-MIDDLE UNIT	BEDROCK	SHALE OR MUDSTONE
Kcml	CEDAR MOUNTAIN FORMATION LOWER-MIDDLE UNIT	BEDROCK	LIMESTONE
			CONGLOMERATE
	FRACTURES		
	POTENTIOMETRIC SURFACE		

FIGURE 4.1

DIAGRAMMATIC CROSS SECTION OF PROPOSED DISPOSAL CELL AND FOUNDATION GREEN RIVER, [illegible]H, TAILINGS SITE

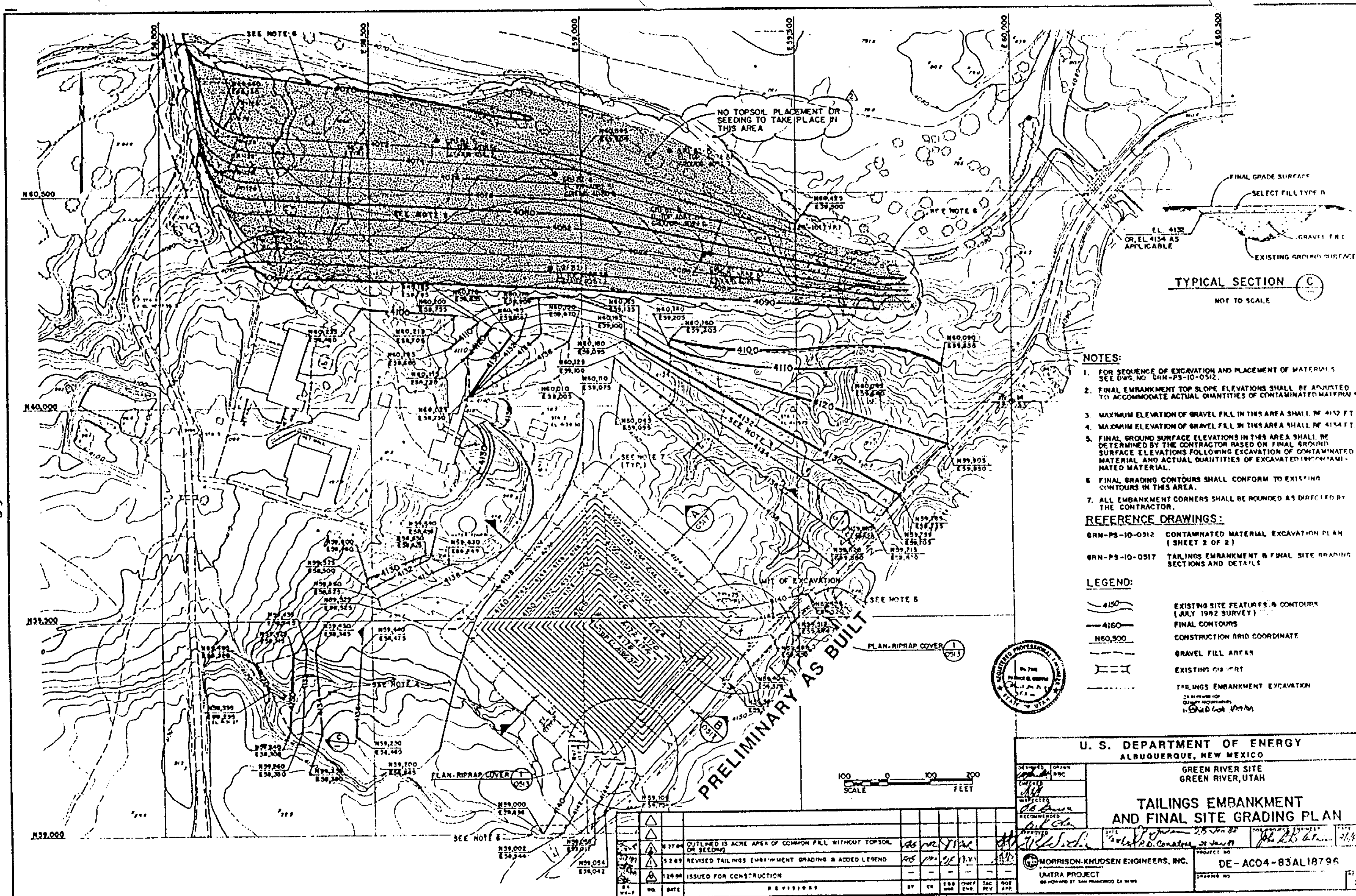


FIGURE 4.2
TAILINGS EMBANKMENT AND FINAL SITE GRADING PLAN

The mill building, crusher building, and office building will be decontaminated to make them suitable for reuse.

Excavated and disturbed disposal site and borrow site areas will be regraded (or backfilled) as required to promote drainage and subsequently revegetated. Areas outside the final disposal site boundary will be released for unrestricted use after completion of remedial action.

4.3.2 Control and monitoring of moisture in contaminated materials and tailings

The specifications for placement of disposal cell materials have been carefully prepared to minimize and control the use of water in order to meet MCLs or background concentrations at the point of compliance (POC) for the identified hazardous constituents. (See Section 2200 of Appendix F.) However, natural precipitation and dust control water could lead to an increase in the moisture content within the disposal cell. A monitoring system is proposed to measure the moisture within the disposal cell during and immediately following construction.

4.3.3 Reprocessing assessment

The cost-effectiveness of reprocessing the tailings to recover the residual uranium has been analyzed (FBDU, 1981). The analysis indicates that capital and operating costs for reprocessing the tailings would be approximately $1600 (1981 dollars) per pound of uranium oxide produced. The present market value of uranium oxide is less than $25 per pound. Reprocessing, therefore, is not economically feasible.

4.3.4 Site acquisition requirements

Legal access to the site will be through purchase of the site from UMETCO by the State of Utah. The site will remain in the ownership of the state during site construction. Following completion of the remedial action, ownership of the permanent diposal site will be transferred to the DOE.

4.3.5 Justification of the Green River design

The EPA standards in 40 CFR 192.02(a)(1) require that control of residual radioactive materials and listed constituents be designed to be effective for up to one thousand years, to the extent reasonably achievable, and, in any case, for at least 200 years. For those sites where the DOE is unable to demonstrate that control measures will clearly be effective for 1,000 years, the DOE must demonstrate that (1) the proposed design represents the best reasonably achievable design to control residual radioactive materials and listed constituents, and (2) control will be effective for some duration in excess of 200 years.

The DOE considers that the Green River disposal unit will control residual radioactive materials and listed constituents in compliance with the EPA standards for at least 1,000 years. The DOE's compliance demonstration with the groundwater protection standards relies on long groundwater travel times between the base of the contaminated materials and the point of compliance. Under expected conditions, the DOE estimates that the travel times will exceed 1,000 years. The travel times, however, may be somewhat less than 1,000 years, but greater than 200 years, considering the uncertainties and limitations of the analyses used to develop the estimates. Therefore, the DOE will herein demonstrate that the disposal unit design is the best reasonably achievable design and that the disposal unit will effectively control residual radioactive materials for at least 200 years to demonstrate compliance with groundwater protection aspects of the EPA standards in 40 CFR 192.02(a)(1).

The DOE has prepared a comparative analysis of alternative disposal designs and concluded that the Green River disposal unit is the best reasonably achievable design to comply with the EPA standards. The following discussion supports this conclusion.

Alternate sites

The DOE considered a representative set of alternative site locations for the disposal of residual radioactive materials from Green River. The set included stabilization in place, stabilization on site (the preferred alternative), and relocation at (1) the northeast Green River site, (2) the southeast Green River site, (3) the Thompson site, and (4) the Woodside site (DOE 1988a; DOE 1986a; and FBDU 1981). Stabilization in place would create a sufficient hazard from flooding by Brown's Wash that the disposal unit may not comply with the EPA standards with respect to long-term stability. Consequently, stabilization in place was rejected as a disposal option. The alternate sites considered did not provide significantly better conditions in terms of groundwater protection because the hydraulic properties and groundwater quality at these sites is similar in many ways to those at the Green River site. Further, relocation of the materials to the alternate sites would increase the cost of the remedial action by $12 million to $38 million because of the site preparation and transportation costs. Therefore, stabilization on site in the area formerly used for ore storage, well above the floodplain of Brown's Wash, is the preferred disposal site alternative.

Disposal cell configuration

The DOE selected partially below-grade disposal of the residual radioactive materials to enhance the long-term stability of the disposal cell. The DOE considered three variables in selecting the configuration of the disposal sell: shape, area, and depth. Assessments of a representative set of alternate shapes indicated that shape has minimal effect on compliance with the groundwater protection standards. The shapes that have the greatest potential to reduce groundwater impacts are difficult to construct and significantly increase the cost of the remedial action compared to the square shape of the preferred design. In addition, some shapes significantly increase the surface areas of the disposal unit; increases in surface area result in corresponding increases in the water flux, and conceivably the flux of listed constituents, through the disposal unit. The square shape is the preferred alternative design with minimum area that is readily constructible.

Given the square shape, the maximum excavation depth of 43 feet has been selected to minimize the surface area of the disposal unit. Greater depths of excavation would place the residual radioactive materials unacceptably close to the water table, which is located approximately ten feet below the preferred excavation depth. The separation distance was selected based on the highest measured water table elevation and the maximum recorded seasonal variation of the water table at the site. Deeper excavation would penetrate through the calcareous shale bedrock into the sandstone layer beneath the site. Deeper excavation could be detrimental by destroying the shale layer, which is a natural barrier to contaminant migration, and by directly connecting the base of the disposal cell with the sandstone unit, which has relatively high hydraulic conductivity. Therefore, the DOE selected the disposal cell configuration to minimize the flux of water and constituents through the cell, to protect against saturation within the cell, and to avoid compromising a natural barrier to contaminant migration.

Buffer layer

The DOE included a buffer layer at the base of the disposal unit to protect against rapid fingering and preferential flow of leachate through the unsaturated zone beneath the unit, to increase the groundwater travel time from the base of the contaminated material to the point of compliance, and to attenuate transport of some listed constituents by adsorption, ion exchange, and precipitation. The DOE considered a number of variables with respect to the design of the buffer layer, including hydraulic properties, sorption characteristics, and thickness.

The DOE considered buffer materials with both lower and higher saturated hydraulic conductivities, ranging from 1E-8 to 1E-3 cm/s, compared with the design saturated conductivity of the buffer layer of 5E-5 cm/s. Once the water flow through the disposal unit reaches steady state, the flux under a unit hydraulic gradient will be controlled by the lowest conductivity to minimize the flux through the disposal unit. Selection of a lower conductivity material for the buffer layer would not significantly improve performance of the disposal unit because the flux rate is governed by the flux through the cover. In addition, the selection of a buffer material with a conductivity equal to or less than the cover conductivity (2E-8 cm/s) could cause adverse accumulation of water above the buffer layer within the disposal (e.g., "bathtubbing"). Such accumulation could cause direct discharge of constituents from the disposal cell. Further, lower conductivity materials may not sufficiently mitigate against fingering and preferential flow of leachate through the unsaturated zone beneath the unit. Finally, because the buffer will operate in the unsaturated state, there is little difference between it and a lower permeability material that would have to be placed at, and thus operate in, a saturated condition.

The DOE proposes to construct the buffer layer out of the selected silty and clayey sand and gravel that overlies bedrock at the disposal site. Although this material does not possess strong sorptive characteristics for the listed constituents at Green River, locally available materials that are suitable for buffer layer construction are not expected to be significantly better than the Green River materials in terms of sorption capacity. The silty and clayey sands and gravels contain interstitial carbonate deposits that may be effective in buffering the pH of leachate from the Green River disposal cell and, thus, reduce the mobility of chromium, Ra-226, arsenic, nickel, lead, and other constituents via precipitation. In addition, oxiferric and alumniohydroxide coatings in the silty and clayey sands and gravels may be effective in sorbing listed constituents such as uranium, arsenic, and radium. Further, the constituents present in the Green River buffer material may not be effective in attenuating all listed constituents. Therefore, materials with better sorptive characteristics than the selected buffer material do not appear to be readily available without a comprehensive search and analysis of alternative materials and considerable expense.

Batch and column feed testing of the buffer material show that the buffer material is effective in reducing feed concentrations of arsenic, molybdenum, selenium, and vanadium (tailings extract solution) to significantly lower concentrations. This testing, with the results, is documented in calculation GRN-07-89-12-07-00 (see Appendix H).

The DOE also considered the thickness of the buffer layer. In general, the buffer layer must be thick enough to provide sufficient travel time between the residual radioactive material and bedrock and to mitigate fingering and yet be thin enough to avoid expanding the surface area of the disposal unit. If the buffer layer were much thinner than the preferred design (e.g., two feet compared with six feet), preferential flow through the buffer layer could become dominant and result in relatively rapid transport of constituents through the fractured bedrock to the water table. In addition, the travel time through the buffer layer would decrease linearly as a function of thickness.

On the other hand, increases in the thickness of the buffer layer (e.g., eight feet compared with six feet) would expand the layer into the volume available to dispose of residual radioactive materials.

Because the base of the excavation is already at a minimum elevation (as discussed above), expansion of the buffer layer would require horizontal expansion of the disposal unit. This expansion would cause a corresponding increase in the surface area of the disposal unit and place more of the residual radioactive materials above the existing ground surface. Such changes could reduce the inherent stability of the disposal cell and may allow the encroachment of nearby gullies and impair the cell's ability to protect groundwater in exchange for a slight gain in travel time and sorption. Further, significant increases in the thickness of the buffer layer would be required to increase travel time through the layer significantly because thickness varies linearly and travel time is directly proportional to thickness. For example, an increase in thickness from six feet to 50 feet would be required to increase the travel time through the buffer layer from 120 years to 1,000 years.

Therefore, the design of the buffer layer has been optimized with respect to groundwater protection by considering its hydraulic properties, sorptive characteristics, and thickness.

Windblown materials

A substantial volume (200,000 cubic yards) of windblown and vicinity property material was found at the Green River site. This material was characterized in terms of leachable hazardous constituents (calculation GRN-07-89-12-07-00 in Appendix H) to determine where within the disposal cell these materials should best be placed. The chemical characterization of the windblown material showed that, for all of the hazardous constituents identified at the Green River site except for uranium and vanadium, the extract concentrations from batch experiments using the windblown materials are below the interim concentration limits proposed by the NRC (and concurred in by the DOE). The column leach tests show, however, that uranium and vanadium feed concentrations are reduced when leached through a laboratory column of buffer material. For these reasons, the windblown materials were considered to be "clean" of leachable hazardous constituents that could impact groundwater quality beneath the disposal cell. The DOE, therefore, optimally placed the windblown and vicinity properties material within the disposal cell between the tailings (upper portion of the cell) and the buffer material (bottom of the cell). It is reasonable to assume, then, that the 25-foot-thick layer of windblown and vicinity property materials acts in a similar manner as the buffer materials and can be included in the calculation of travel times to the base of the disposal cell (calculation GRN-07-89-03-04) from the overlying tailings (see Section E.3 of Appendix E).

Moisture contents

The DOE will construct and maintain the materials comprising the disposal cell at moisture contents near that of the average steady state moisture contents. Moisture contents of the disposal unit materials must be minimized to avoid the drainage of water added during the construction. Such drainage could significantly reduce groundwater travel times to the point of compliance and temporarily increase the transport of listed constituents out of the unit. However, if moisture contents are too low, the DOE may have difficulty compacting materials to the densities required to ensure the long-term geotechnical stability of the disposal unit and maintain airborne particulate concentrations and releases below appropriate state and Federal regulatory limits. As an alternative, the DOE considered adding a surfactant or other chemical agent to suppress fugitive emissions of dust and contaminated materials. However, because surfactants only treat the surface, construction traffic would make them ineffective almost immediately following application. In addition, such treatments add organic chemicals to the residual radioactive materials that may increase the release of contaminants and reduce the effectiveness of the disposal unit in protecting groundwater. The DOE can achieve the density specifications and control airborne emissions at moisture contents down to the approximate steady state moisture contents reported in the RAP. Calculation GRN-07-89-03-04 supports the concept that some variation of placement moisture content can be tolerated without causing excessive impact on travel time.

The DOE has committed to maintain moisture contents as low as reasonably achievable in the buffer and residual radioactive materials layers and in accordance with the steady state moisture contents identified in the April 5, 1989, agreements between the DOE and the NRC. Although lower moisture contents could increase groundwater travel times and decrease constituent transport to the point of compliance, imposition of measures to attain these contents could result in violations of the fugitive emission requirements and decrease the stability of the disposal unit. Thus, the steady state moisture contents are the optimum moisture contents for groundwater protection.

Radon barrier

The DOE has proposed a radon barrier consisting of three feet of silty clay amended with six percent by weight sodium bentonite that is compacted to 100 percent of the standard Proctor density. The DOE is confident that the barrier will have a saturated hydraulic conductivity less than 2E-8 cm/s and agrees to test as-constructed samples of the barrier to ensure compliance with this design conductivity. The DOE considered alternative cover designs to reduce potential infiltration into the disposal unit further, including substitution of synthetic polymeric membranes, CLAYMAX[R], or other alternatives for the silty clay barrier; increased thicknesses of the barrier; and increased percentages of bentonite in the barrier.

The DOE assessed the viability of alternative barriers in generic special studies that were initiated in response to the EPA's proposed groundwater protection standards in 40 CFR 192. The results of these studies are documented in "Remedial Action Planning and Disposal Cell Design" (DOE, 1989b). Based on the studies, the DOE concluded that only conventional earthen covers and CLAYMAX could be relied upon for long-term (1,000 years) protection of groundwater at disposal sites because of the inherent stability of synthetic materials and the limited operational experience with such materials. The DOE considered installing a thin layer of CLAYMAX in the cover to attain a net flux density equal to or less than 1E-9 cm/s. Based on analyses of the Green River site, the DOE concluded that the minimal improvement in performance of the disposal unit associated with a composite cover that included CLAYMAX would not adequately justify the significant increase in cost. In addition, the DOE would have to resolve substantial issues about the long-term durability and performance of CLAYMAX prior to including it in the disposal unit cover. Thus, the DOE rejected CLAYMAX because it was not a reasonable alternative.

The DOE also considered increasing the thickness of the bentonite-amended radon barrier. Increases would not significantly improve the long-term performance of the barrier. At least one foot of the barrier is located below the frost penetration zone and, thus, would be expected to provide a barrier with sufficiently low permeabilty to infiltration to minimize release of listed constituents. The barrier would be effective in reducing infiltration of water into the disposal unit to below 2E-8 cm/s. Thus, increasing the thickness of the radon barrier would only increase the cost of the remedial action without significantly improving the performance of the barrier.

The DOE considered increasing the content of sodium bentonite above the six percent by weight in the current design. Based on laboratory testing data on file at the UMTRA Project Office, the DOE concluded that further amendment of the radon barrier with sodium bentonite would not significantly decrease the hydraulic conductivity of the barrier. The specified hydraulic conductivity for the radon barrier of 2E-8 cm/s is approximately one order of magnitude below the generally accepted design conductivity of 1E-7 cm/s for compacted clay liners and covers at municipal and hazardous waste landfills. Attainment of the 2E-8 cm/s conductivity is considered to be the best and most reasonably achievable in terms of construction of earthen barriers to water and contaminants. Consequently, a six percent sodium bentonite admixture represents the optimum modification of the radon barrier with respect to groundwater protection because further increases in bentonite content do not improve performance of the cell.

Filter layer

The DOE has selected a high permeability filter layer above the radon barrier to enhance lateral runoff of incident precipitation off the disposal unit to further minimize infiltration. The hydraulic conductivity of the filter layer has been optimized at a conductivity of four cm/s (Calculation GRN-07-89-03-04) using a relatively clean sand and gravel. Lateral diversion of runoff could be increased, thus decreasing infiltration, by increasing the hydraulic conductivity of the filter layer above four cm/s. However, the runoff may be so rapid under such conditions that the water would erode the radon barrier, which could potentially increase infiltration and radon emissions and decrease stability of the disposal unit. The DOE also considered decreasing the thickness of the filter layer to ensure that the carrying capacity of the layer is minimized to divert runoff from the pile through the riprap under the design storm events. Such a decrease in thickness could lessen infiltration into the radon barrier by decreasing the amount of time that water would be ponded above the radon barrier on the sideslopes of the disposal unit. However, literature supports the concept that a decrease in bedding layer thickness may result in reduced erosional stability (Anderson et al., 1970). Further, calculations (GRN-07-89-03-04) show that by increasing the bedding permeability, little additional effect is gained by further changes to the cover geometry. Therefore, the filter layer has been optimized with respect to groundwater protection by ensuring that the thickness and hydraulic conductivity of the layer are large enough to divert runoff laterally off the side slopes of the disposal unit, yet not so high that the runoff would significantly degrade the performance of the disposal unit by eroding the radon barrier.

Source modifications

The DOE considered the viability of source modifications such as geochemical amendments to the residual radioactive materials and thermal stabilization of the materials. Such modifications were assessed generically for the UMTRA Project in special studies (DOE, 1989b). The DOE used the special studies to identify alternatives that deserved additional investigation because they may be viable on a site-specific basis. The DOE considered a representative range of source control alternatives for the Green River site, including washing, thermal stabilization, the addition of peat to reduce uranium and nitrate releases, and the addition of calcium hydroxide. Washing and thermal stabilization were rejected as unreasonable because they would significantly increase (i.e, from two to five times) the costs of the remedial action without demonstrably improving the long-term performance of the disposal unit in terms of groundwater protection. In addition, the washing alternative would require extensive engineering development, permitting, and operation to reduce the volume of the waste but would not significantly reduce the hazards associated with the listed constituents.

The DOE considered adding peat to the contaminated materials and concluded that the peat would not be expected to reduce the release of all constituents, even though it may sorb uranium and several other metals and reduce nitrate to less mobile species. As discussed previously, listed constituents in the residual radioactive materials are mobile under a variety of geochemical conditions and no one environment is expected to attenuate all the constituents. In addition, geochemical amendments such as peat have been studied only in the laboratory; such amendments have not been attempted in either bench- or field-scale applications. The laboratory studies have not provided conclusive results regarding the effectiveness of such amendments in attenuating the release of listed constituents from uranium tailings. Thus, there is considerable uncertainty about whether such amendments would be effective in reducing the release of listed constituents from the Green River disposal cell. Further, the addition of peat would significantly increase the cost of remedial action at the site and could decrease the stability of the site as a result of the organic degradation of the peat (Thompson, 1988). Therefore, the DOE concluded that a peat amendment was not a reasonable alternative for the Green River site.

The DOE also considered adding calcium hydroxide or another alkaline chemical agent to increase the pH of the residual radioactive materials. The increase in pH would be expected to decrease the solubility and mobility of listed constituents that are less soluble under neutral to alkaline pHs. However, the residual radioactive materials already have pHs that are in the range of neutral (e.g., six to eight) and further increases in pH could significantly increase the mobility and solubility of listed constituents such as uranium, molybdenum, and selenium as a result of complexion with hydroxide, carbonate, and bicarbonate radicals. Such behavior has been observed at other uranium tailings sites where alkaline groundwaters have been contaminated with tailings seepage or alkaline solutions were used to leach the uranium. Thus, the addition of calcium hydroxide as an amendment in the disposal unit would be expected to have an adverse impact with respect to the protection of groundwater (NRC, 1985b; NRC, 1984; NRC, 1983). Therefore, the DOE determined that calcium hydroxide or other alkaline chemical amendments to the disposal unit are inappropriate because they could actually decrease the effectiveness of the unit in terms of groundwater protection.

Contaminated material testing

The NRC normally requires testing to verify the placement density and moisture content of contaminated materials (including tailings, windblown contaminated soil, and vicinity property material) placed in the disposal cell at a frequency of one test per 1,000 cubic yards of material placed. Specifications for UMTRA Project sites constructed prior to the Green River disposal cell generally required contaminated material to be placed at 90 percent of standard Proctor density. In evaluating this practice the DOE was concerned that the remedial action subcontractor would not be restricted in the amount of water that could be added for compaction. Realizing that the moisture content at placement would be very important to attaining the groundwater protection strategy, the DOE proposed a contaminated material placement specification that would minimize the amount of water that could be added. The specification (see section 2200, 3.5, C. of Appendix F) states that contaminated materials would be compacted to 90 percent of standard Proctor by a minimum number of passes of a tamping foot or vibratory roller to be determined during initial placement of the first 1,000 cubic yards of windblown materials and tailings. This approach is appropriate because the materials were determined to be homogeneous within types (tailings and other contaminated material) and compaction for soils with similar particle gradations could be predicted from a review of literature and laboratory test data.

Considering the homogeneous nature of the contaminated materials (see Section D.4 of Appendix D), testing to verify placement density, and moisture content, a testing frequency of one test per lift was proposed by the DOE. Approximately 6,000 cubic yards or less of contaminated material would be included in each nine-inch-thick lift.

Further explanation of the testing of contaminated materials and the results of the tests are included in the calculation volume with the title "Green River, Utah, Contaminated Material Moisture Content, Density, and Compaction Data" accompanying this RAP and available through UMTRA Project Document Control, Albuquerque, New Mexico.

Conclusion

The DOE has considered a representative range of alternate disposal actions for the residual radioactive materials at the Green River site. Based on this assessment, the DOE concludes that the present disposal unit design represents the best design that is reasonably achievable to comply with the proposed EPA standards.

4.4 PERMANENT DESIGN FEATURES

4.4.1 Introduction

Permanent design features are described in more detail below for the cleanup of the mill site and adjacent areas and for stabilization of the disposal embankment. Factors considered in the design, including subsurface conditions, engineering properties of the tailings, groundwater protection, and requirements for erosion and radon control, are described and their effect on layout and construction of the disposal embankment are discussed.

4.4.2 Contaminated material excavation

Contaminated materials will be excavated and stockpiled. Areas that will be excavated and the corresponding excavation depths are shown on Figures 4.3 and 4.4. After these materials are excavated, the contractor will determine if these areas or other areas require additional excavation.

Stockpiled contaminated materials will be placed in the disposal embankment once the embankment excavation is completed.

4.4.3 Demolition of existing buildings

Six buildings are present on the former mill site. The location of these buildings are shown on Figure 4.5.

The roaster building, the office building addition, and the mill building addition will be demolished because it is not practical to decontaminate them. Debris that results from demolition will be placed in the disposal embankment. Demolition will be conducted in a manner that will protect workers and that will minimize release of airborne contamination.

4.4.4 Decontamination of existing buildings

The crusher building, the mill building, and the office building will be decontaminated in order to make them suitable for future use. Decontamination will include:

- Washing building walls, ceilings, and floors.

- Excavating contaminated soil and utilities that are located beneath the buildings.

4.4.5 Disposal embankment location

Stabilization on site of the tailings and other contaminated materials is the preferred disposal option. The Environmental Assessment (DOE, 1988a) concludes that stabilization on site is preferred because it is an economic solution that has equivalent or lesser environmental impacts than the other disposal options that were considered.

4.4.6 Disposal embankment layout

A description of the disposal embankment at the completion of remedial action work is provided in Section 4.3.1. The final embankment layout is shown on Figure 4.2. All contaminated materials will be buried in the disposal embankment. The surface area of the embankment has been reduced to the smallest practicable size

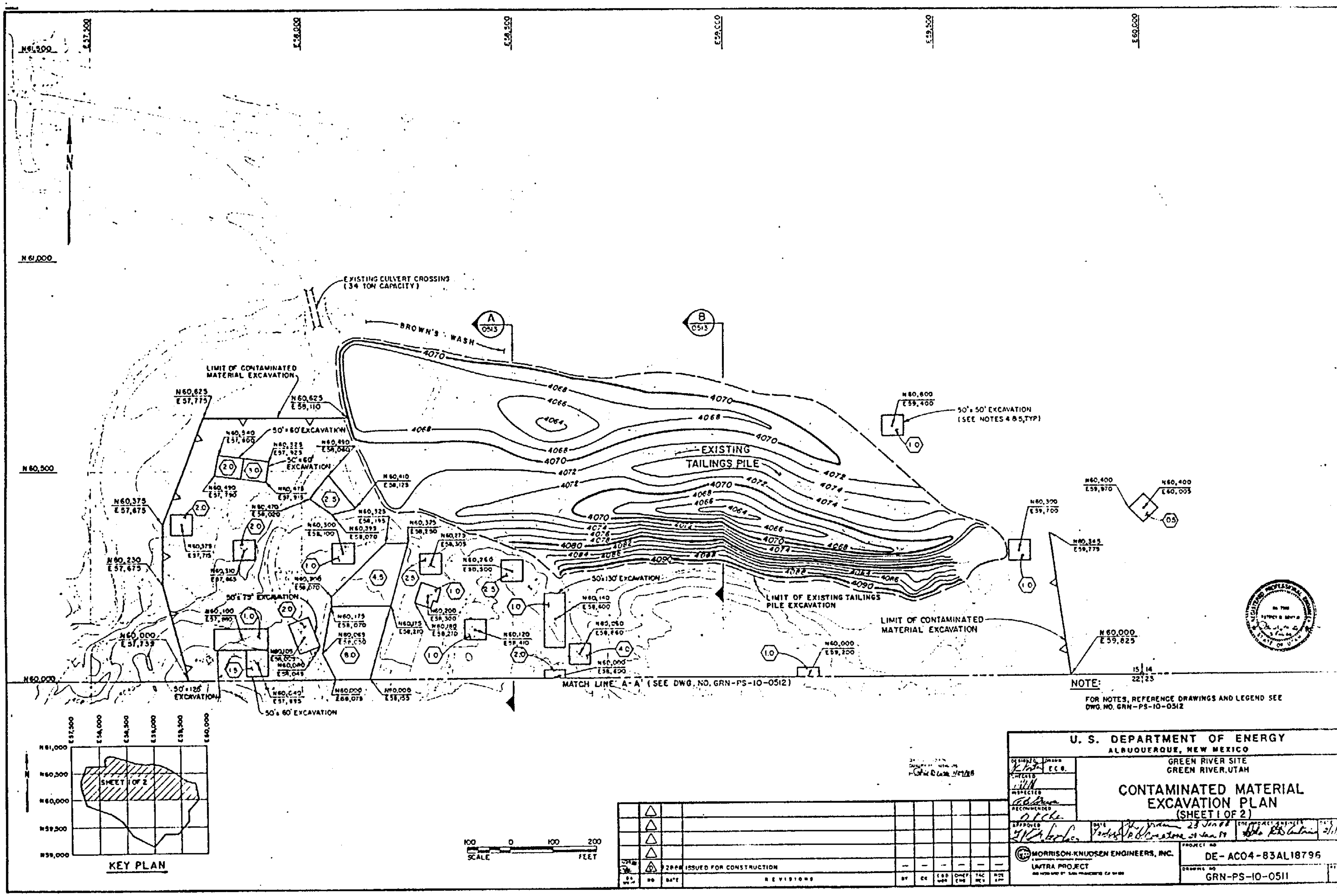


FIGURE 4.3

CONTAMINATED MATERIAL EXCAVATION PLAN

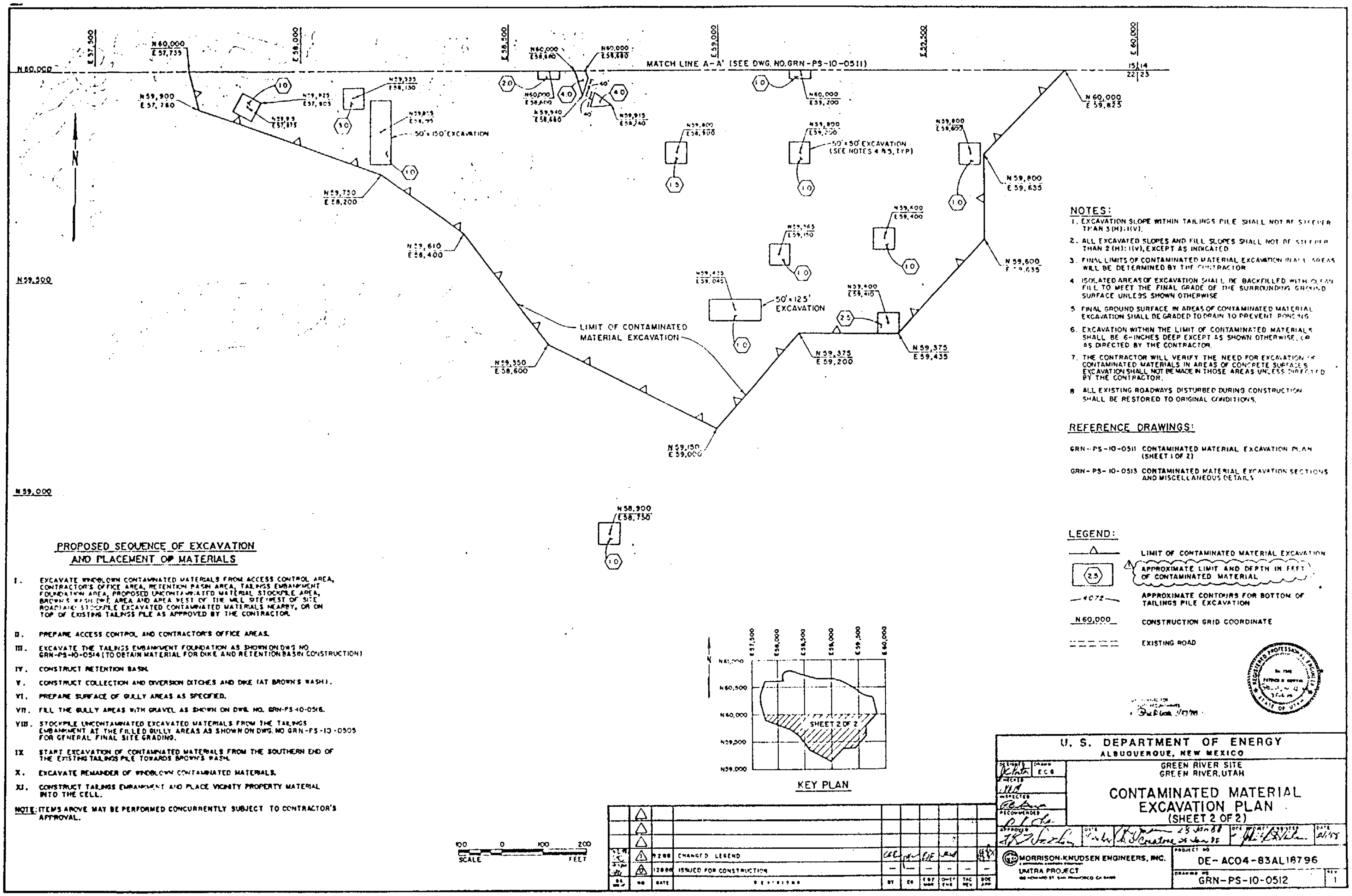


FIGURE 4.4
CONTAMINATED MATERIAL EXCAVATION PLAN

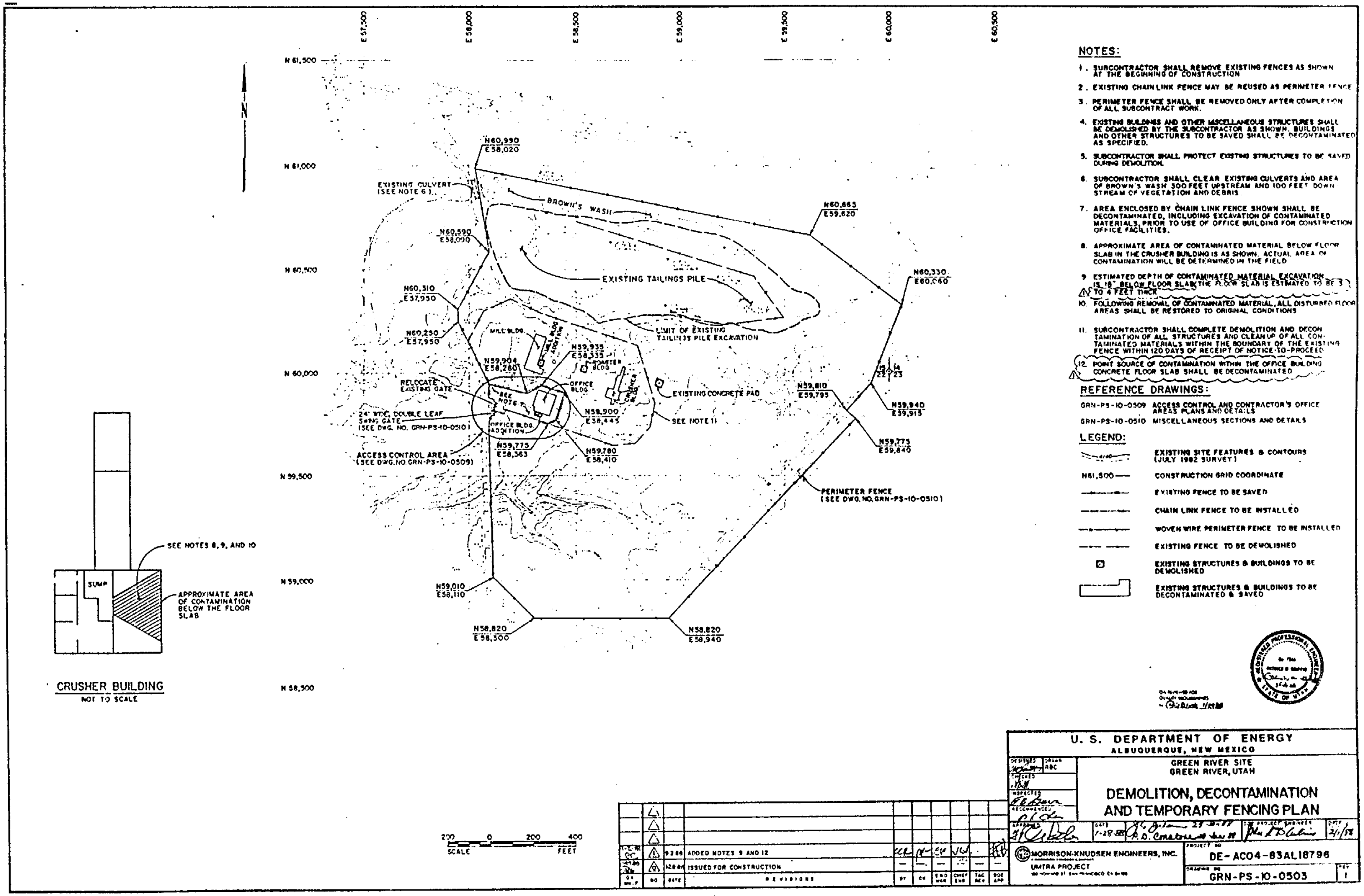


FIGURE 4.5
DEMOLITION, DECONTAMINATION AND TEMPORARY FENCING PLAN

to minimize quantities of erosion protection materials and the amount of future infiltration into the tailings, and to provide the maximum buffer zone from Brown's Wash.

4.4.7 Geotechnical considerations

The principal geotechnical considerations used to design the disposal embankment are slope stability, liquefaction, settlement, and gully formation.

Analysis of slope stability was made for static and dynamic (earthquake) conditions. Earthquake conditions were simulated using a pseudo-static approach. The pseudo-static coefficient, or horizontal acceleration, was set equal to two-thirds of the maximum site horizontal acceleration given in Appendix D. Strength values for tailings, select fill, and infiltration/radon barrier materials were based on laboratory tests. Conservative strength values were used for bedding and riprap materials. The slope stability analysis concluded that slopes will remain stable under static and dynamic conditions.

Materials in the disposal embankment will be compacted to increase strength and reduce compressibility. Tailings and contaminated materials will remain unsaturated, based on assessment of site climate, surface grading, subsurface conditions, and reduced infiltration due to the relatively impermeable infiltration/radon barrier. Thus, there is no potential for strength loss and settlement that could be caused by liquefaction or by dynamic densification.

The total long-term settlement of material in the disposal embankment will be very small due to compaction of the embankment materials. Settlement of the bedrock foundation will be negligible. Therefore, the potential hazards of settlement, including differential settlement-induced cracking of the infiltration/radon barrier, are considered to be acceptably small.

4.4.8 Surface hydrology

The disposal embankment site is above the elevation of the PMF elevation in Brown's Wash. The only off-site water that could affect the integrity of the embankment, therefore, would come from the watershed located between the disposal site and I-70. Erosion protection on the southeast side of the embankment will protect against such runoff. For additional protection, this water will be diverted from the disposal embankment by ditches constructed along the southeast side of the disposal embankment. The ditches are designed to carry runoff from ordinary storms away from the embankment perimeter and to reduce runoff velocities below erosive velocities. Only runoff from large precipitation events would flow against the embankment.

4.4.9 Erosion protection

Rock layers placed on the embankment will protect against erosion. Rock sizes are designed to resist erosive forces of runoff from precipitation that will fall directly on the embankment and runoff from the watershed located southeast of the embankment. Riprap toe protection will extend about 20 feet on the surface from the embankment toe to reduce erosion of the ground surface adjacent to the embankment.

Migration of infiltration/radon barrier material or select fill cover materials will be prevented by an overlying layer of bedding. A layer of Type A riprap will be placed between Type B riprap and bedding to prevent the migration of bedding into Type B riprap.

The Utah Department of Transportation quarry at Fremont Junction, Utah, will be the source of Type B riprap and Type A riprap. The durability of rock from this source was determined to be satisfactory to meet the requirements of NUREG/CR-4620 to resist long-term weathering based on the results of tests performed on rock samples obtained from the quarry. The test results are presented in Appendix D of the February 1988 RAP. The subcontractor will be allowed to use rock from another source if it can be demonstrated that the alternate rock source is equivalent to the Fremont Junction rocks. Bedding will be obtained from the same borrow site as used for the infiltration/radon barrier material.

Table 4.1 summarizes the requirements for riprap and bedding materials.

The remedial action plan includes the following measures to reduce the hazard of the undermining of the disposal embankment by long-term erosion, including enlargement of existing gullies and formation of new gullies:

- Filling the gullies.

- Constructing riprap protection along the disposal embankment toe that will protect the embankment against erosion in the event that gullies form adjacent to the disposal embankment. Details of the riprap toe protection are presented in Section 4.3.1.

- Grading the site to promote sheet flow and reduce flow concentrations that might cause gully formation.

4.4.10 Infiltration/radon control

An infiltration/radon barrier consisting of uncontaminated soil mixed with six percent bentonite by weight will be constructed over the tailings to limit emanation of radon to the levels set by

Table 4.1 Erosion protection requirements for disposal embankment

Location	Particle size requirements (inches)	Volume (cy)
Bedding	$0.04 \leq D_{50} \leq 0.2$ $0.75 \leq D_{100} \leq 3.0$	4,800
Type A Riprap	$2.6 \leq D_{50} \leq 3.5$ $3.2 \leq D_{100} \leq 4.4$	10,100
Type B Riprap	$18.0 \leq D_{50} \leq 23.5$ $22.5 \leq D_{100} \leq 30.5$	16,000

EPA standards and to inhibit infiltration into underlying tailings. The three-foot-thick infiltration/radon barrier will be placed at sufficient depth to ensure that at least 12 inches of infiltration/radon barrier are below the frost depth.

Based on measurements of current contamination levels, a 12-inch-thick infiltration/radon barrier is satisfactory to reduce radon flux beneath 20 pCi/m^2s. The thickness of the infiltration/radon barrier will be verified during construction based on radiation data from in-place contaminated materials, but would not be less than three feet.

Silty clay obtained from the designated borrow site located three miles north of the project site will be used to construct the infiltration/radon barrier. Geotechnical tests, including compaction, shear strength, and permeability tests, were performed on soil samples obtained from this source. Results of the test program are included in Appendix D.4 of Volume IIA of the January 1989 RAP and in the Information to Bidders volume. Based on these results, it is concluded that the infiltration/radon borrow material, when mixed with six percent of bentonite by weight and compacted to 100 percent of maximum dry density based on ASTM D-698, will produce an average saturated hydraulic conductivity of 2×10^{-8} cm/s, or less. Construction features that will be used to protect against defects in the infiltration/radon barrier that might increase permeability include:

- o Provide a minimum three-foot-thick barrier to reduce the potential for localized flow paths due to construction irregularities.

- o Provide a rough surface between lifts by scarifying prior to placement of overlying lift.

- Provide uniform moisture distribution by "moisture-curing" infiltration/radon barrier materials before compaction.

- Facilitate uniform layer properties by restricting clod sizes to one inch or smaller.

- Control water used for compaction and dust control.

4.4.11 Economic considerations

To the extent practical, the remedial action plan is designed to result in the minimum construction cost that is consistent with design standards, safe construction practices, and other applicable criteria. The EPA standards will be met by stabilizing contaminated material on the site as described above. Stabilization of contaminated materials on the site is less expensive and creates fewer environmental impacts than moving them to a new disposal site. Minimizing the surface area of the embankment reduces the cost of surface and perimeter erosion protection. The use of on-site excavated soils for site grading and cover is made to the maximum extent practicable to reduce costs.

4.5 CONSTRUCTION FEATURES

4.5.1 Overview

Construction features are described below to provide an overview of implementation of remedial action. Construction features include staging areas, decontamination facilities, temporary drainage ditches, wastewater collection and retention systems, a dike to protect the existing tailings pile, and construction offices. Locations and sizes of construction features may be changed to facilitate construction activities.

The office building will be decontaminated at the beginning of construction to allow it to be used as an office by the DOE, the contractor, and the radiological subcontractor.

A woven wire perimeter fence will be constructed around the site to control traffic in and out of the site and to prevent unauthorized entry to the site. Access to the site will be by means of a gate on the site road located about 200 feet west of the decontamination pad. The decontamination pad will be constructed immediately south of the existing mill site buildings (see Figure 4.6). Vehicles leaving contaminated areas will be monitored and washed, if necessary, to prevent the spread of contamination.

Temporary diversion ditches will prevent surface water runoff from entering the site during remedial action operations. Collection ditches on the site will channel on-site contaminated runoff water to the wastewater retention basin or to low areas where runoff can be pumped to the retention basin.

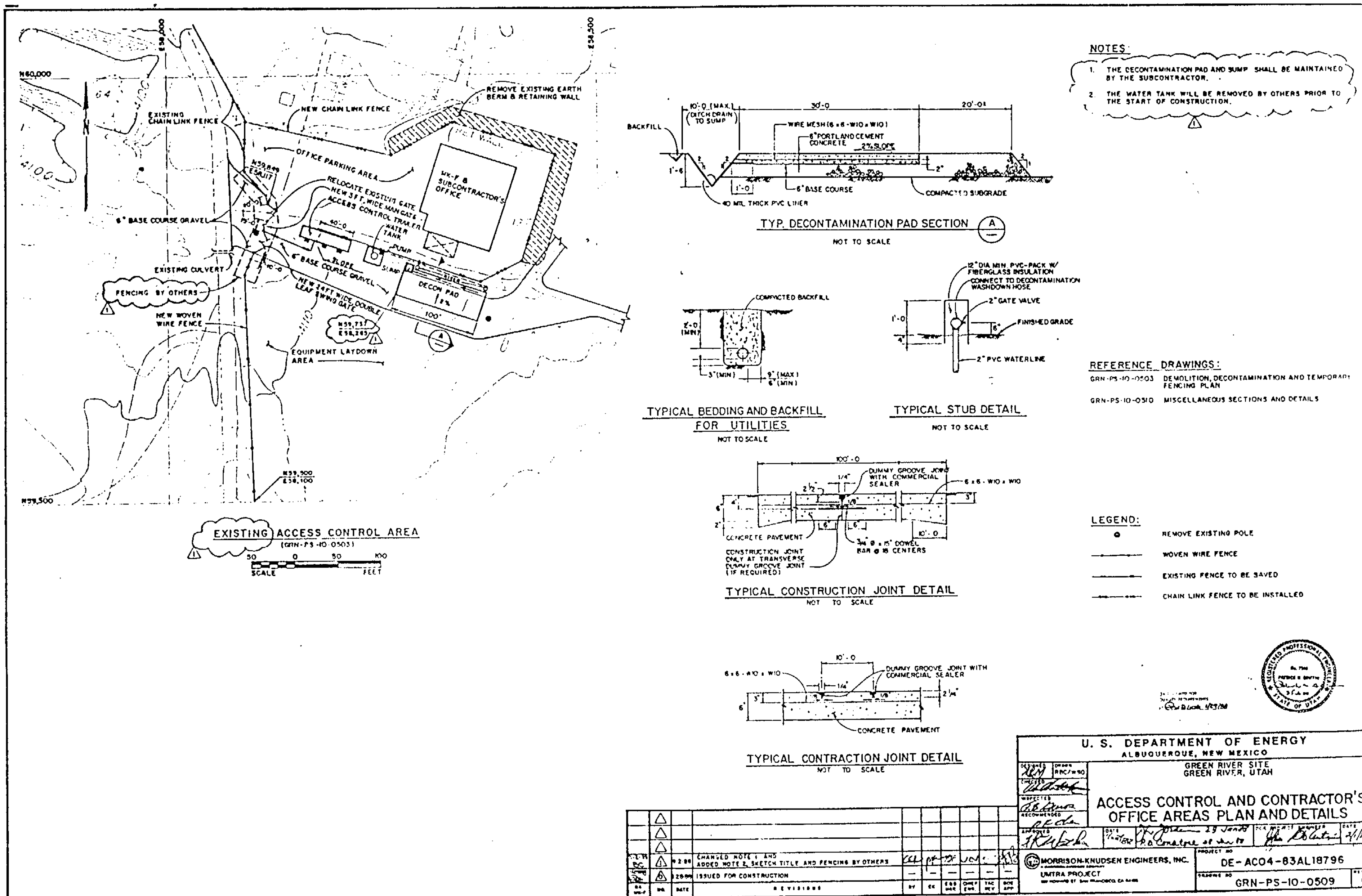


FIGURE 4.6
ACCESS CONTROL AND CONTRACTOR'S OFFICE AREAS PLAN AND DETAILS

Uncontaminated material from the disposal embankment excavation will be stockpiled along the south bank of Brown's Wash to protect the retention basin and tailings pile from a 100-year flood on Brown's Wash. (This design feature is included at the request of the state of Utah.)

Contaminated materials will be transported on temporary haul roads and on existing permanent roads.

The following utilities are available at the site:

- o Electricity (Utah Power and Light).
- o Telephone (Mountain Bell).
- o Water and sewer (city of Green River).

Locations of these utilities are presented on Figure 4.7.

4.5.2 Drainage, erosion control, and wastewater retention basin

Surface water runoff from uncontaminated areas will be diverted to off-site areas. Surface water runoff from contaminated areas will be collected and drained to a retention basin.

Contaminated runoff will either be retained in the retention basin and evaporated or treated as necessary and discharged. To the extent practical, contaminated water will be evaporated or used for compaction water to moisture-condition tailings and other contaminated materials. Treatment and discharge may be necessary if runoff during the construction period exceeds the basin capacity, or if the water in the retention basin does not evaporate before completion of construction. Controlled discharges from the retention basin would meet effluent limits established by a National Pollutant Discharge Elimination System (NPDES) permit. Emergency uncontrolled discharge would be used only if necessary to prevent failure of the retention basin.

Diversion ditches are designed to carry runoff resulting from a PMP event. This will prevent uncontaminated runoff from entering the site. Wastewater collection ditches are designed to carry peak flow from a 10-year storm to the retention basin.

The wastewater retention basin will receive discharge from:

- o Runoff from contaminated areas.
- o Dewatering of the existing tailings area, if required.
- o Decontamination of trucks and other equipment.
- o Washbasin and shower facilities.

The retention basin at the site is sized to retain runoff resulting from a 10-year, 24-hour storm in addition to the maximum storage required for normal storm water runoff and wastewater generated from remedial action activities. The retention basin

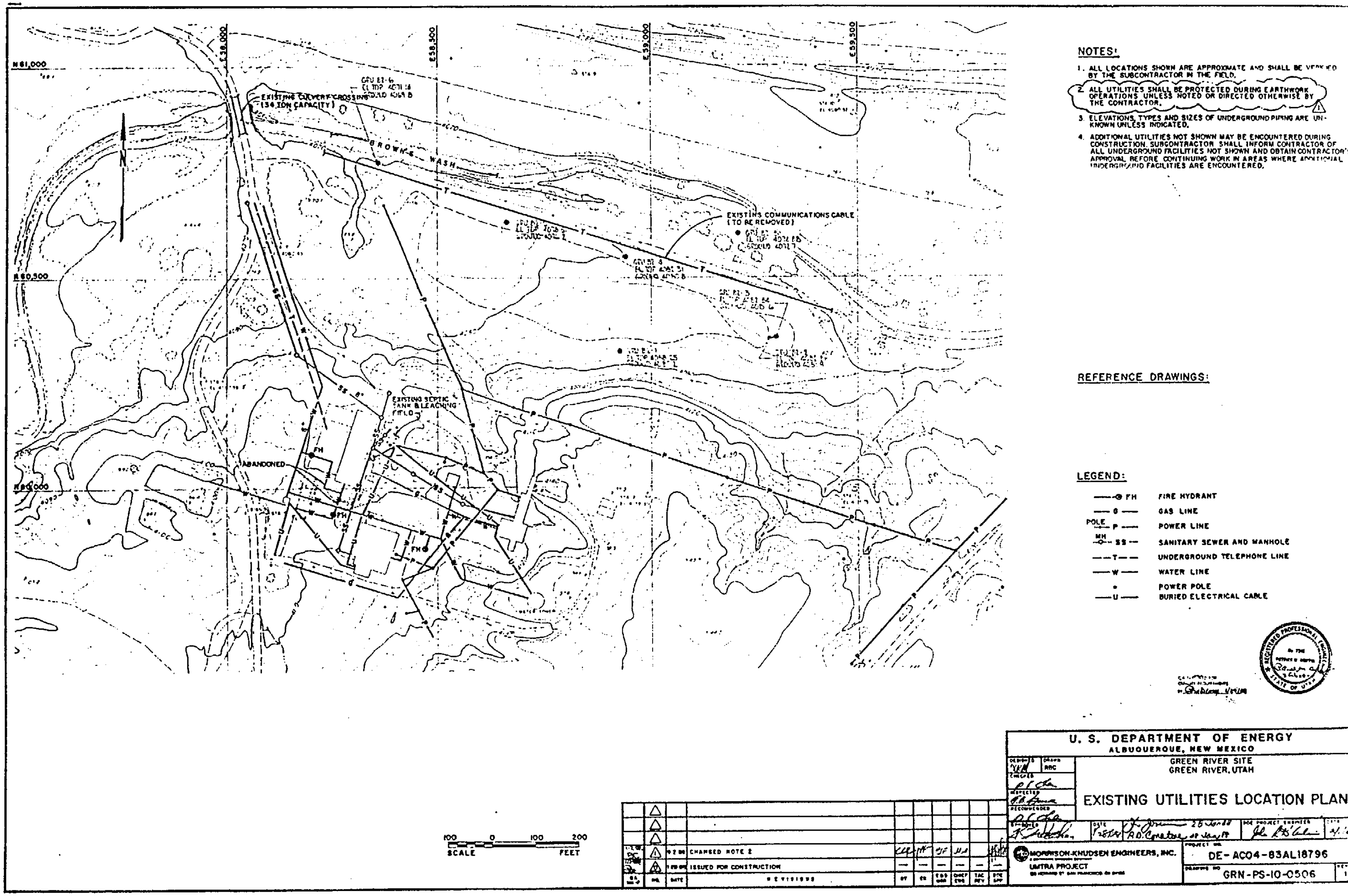


FIGURE 4.7
EXISTING UTILITI(.OCATION PLAN

will also have sufficient capacity to hold the total estimated sediment inflow during construction operations. The basin spillway will safely discharge peak runoff from a 25-year storm and maintain one foot of freeboard between the top of the embankment and the water surface at a time when the spillway is flowing at design elevation.

4.5.3 Existing buildings

The mill building addition, the office building addition, the roaster building, and all other abandoned equipment at the mill site will be demolished. Debris resulting from the demolition will be buried in the disposal embankment. All demolition activities will be controlled to protect workers and to restrict release of airborne contamination. Contaminated material will not be removed from the site.

The mill building, crusher building, and office building will be decontaminated to make them suitable for reuse.

4.5.4 Dewatering

If water is encountered during excavation of the existing tailings pile, dewatering may be performed to facilitate excavation. Water resulting from dewatering operations will be pumped into the retention basin.

4.5.5 Equipment decontamination pad

Equipment leaving contaminated areas will be monitored for contamination. To prevent contaminated materials from being carried out of areas, a decontamination pad with a holding tank and pump will be provided to wash contaminated equipment.

4.5.6 Dust control

Dust generated by excavation, earth movement, vehicle use, temporary stockpiling of materials, and similar activities will be controlled by spraying water and/or water-based surfactants. Special care will be taken to control dust created by the decontamination and demolition of buildings and by temporary stockpiling or mixing of contaminated materials.

Schedules for spraying the roads and embankment areas will vary daily and will be adjusted as required. The frequency of spraying will increase when combinations of low soil moisture and high wind speed are encountered.

4.5.7 Borrow areas

The approximate location of the radon barrier and bedding material borrow area is shown on Figure 4.8. Type B riprap and Type A riprap will be obtained from a boulder, cobble, and gravel deposit at Fremont Junction, approximately 75 miles west of the site.

4.5.8 Archaeological sites

No historic or cultural resources have been identified at the tailings or at the radon barrier borrow site. Cultural resource clearance will be obtained for all areas to be disturbed during construction, including the riprap and bedding borrow sources.

4.5.9 Construction sequence

The following construction sequence is planned for the remedial action. However, the construction subcontractor will be allowed to execute the work within the constraints of project specifications. The actual construction sequence, therefore, may differ from the planned sequence.

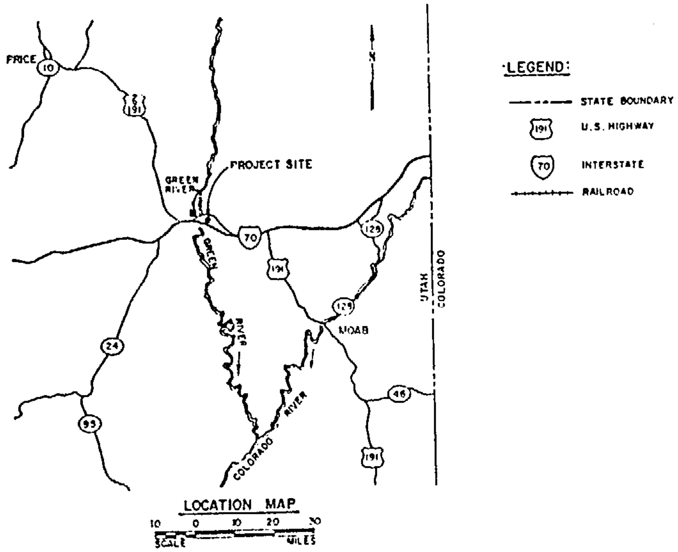
The first item of construction will be the establishment of a site security system including erection of the perimeter fence. This will provide a means for control of traffic entering and leaving the site. Immediately thereafter, contaminated materials in the decontamination pad and staging areas will be excavated and stockpiled. The decontamination pad slab will then be constructed.

The next major item of site preparation will be construction of the retention basin and drainage ditches. Materials excavated during these operations will be stockpiled for subsequent use as fill. Site drainage will be improved by clearing the floodplain of Brown's Wash where it flows under the site road and clearing the clogged culverts that drain the small drainage immediately east of the site.

Concurrent with these activities, any necessary construction and/or upgrading of access roads and haul roads will be performed.

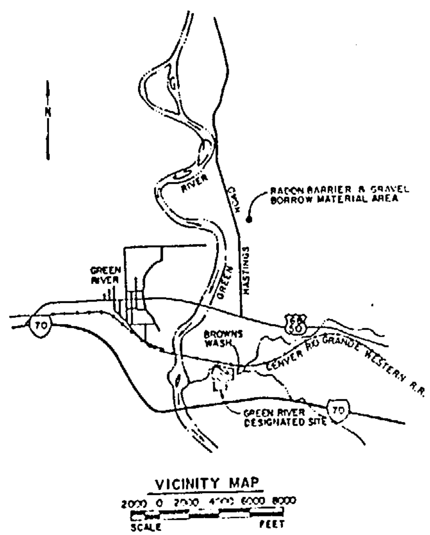
After the initial site preparation is completed, earthwork at the disposal area will begin. This will involve excavation and stockpiling of materials to allow for below-grade disposal of contaminated materials. Some excavated materials will be stockpiled near Brown's Wash in the form of a dike to provide flood protection as discussed in Section 4.5.1.

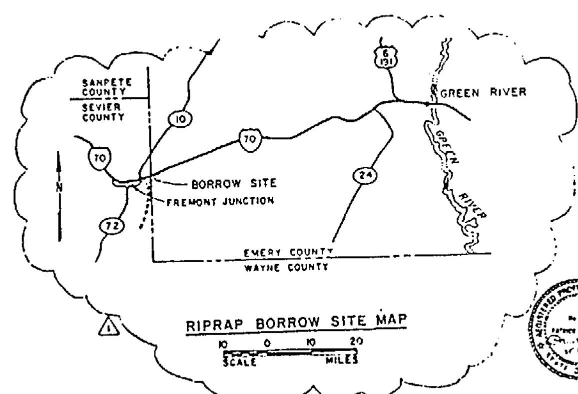
Concurrently, demolition of the mill building addition, the office building addition, and the roaster building and decontamination of the crusher, mill, and office buildings will proceed.



LIST OF DRAWINGS

DRAWING NO.	DRAWING TITLE
GRN-PS-10-0501	TITLE SHEET
GRN-PS-10-0502	LOCATION MAP, VICINITY MAP AND LIST OF DRAWINGS
GRN-PS-10-0503	DEMOLITION, DECONTAMINATION AND TEMPORARY FENCING PLAN
GRN-PS-10-0504	FINAL SITE PLAN
GRN-PS-10-0505	CONSTRUCTION FACILITIES AND SITE DRAINAGE
GRN-PS-10-0506	EXISTING UTILITIES LOCATION PLAN
GRN-PS-10-0507	HORIZONTAL AND VERTICAL CONTROL
GRN-PS-10-0508	WASTEWATER RETENTION BASIN PLAN AND DETAILS
GRN-PS-10-0509	ACCESS CONTROL AND CONTRACTOR'S OFFICE AREAS PLAN AND DETAILS
GRN-PS-10-0510	MISCELLANEOUS SECTIONS AND DETAILS
GRN-PS-10-0511	CONTAMINATED MATERIAL EXCAVATION PLAN (SHEET 1 OF 2)
GRN-PS-10-0512	CONTAMINATED MATERIAL EXCAVATION PLAN (SHEET 2 OF 2)
GRN-PS-10-0513	CONTAMINATED MATERIAL EXCAVATION SECTIONS & MISCELLANEOUS DETAILS
GRN-PS-10-0514	TAILINGS EMBANKMENT FOUNDATION EXCAVATION PLAN
GRN-PS-10-0515	TAILINGS EMBANKMENT FOUNDATION SECTIONS
GRN-PS-10-0516	TAILINGS EMBANKMENT AND FINAL SITE GRADING PLAN
GRN-PS-10-0517	TAILINGS EMBANKMENT AND FINAL SITE GRADING SECTIONS AND DETAILS
GRN-PS-10-0518	MONITOR WELL ABANDONMENT AND BORING LOCATION PLAN





U. S. DEPARTMENT OF ENERGY
ALBUQUERQUE, NEW MEXICO

GREEN RIVER SITE
GREEN RIVER, UTAH

LOCATION MAP, VICINITY MAP AND LIST OF DRAWINGS

MORRISON-KNUDSEN ENGINEERS, INC.
UMTRA PROJECT

PROJECT NO. DE-AC04-83AL18796

DRAWING NO. GRN-PS-10-0502

ADDED RIPRAP BORROW SITE MAP

ISSUED FOR CONSTRUCTION

REVISIONS

FIGURE 4.8

LOCATION MAP, VICINTY MAP, AND LIST OF DRAWINGS

The tailings pile, windblown tailings, and other contaminated materials will be excavated and placed on a six-foot-thick layer of select fill in the disposal cell. The movement of contaminated materials will not begin until upgrading of the haul and access roads has been completed and until a sufficient area has been opened and approved at the disposal area. After the contaminated materials are in place, the infiltration/radon barrier will be constructed over the disposal embankment. Appropriate measures will be taken during the winter shutdown to ensure that tailings or contaminated material in the disposal cell are not unnecessarily exposed to erosional forces or precipitation and runoff.

The final construction phase will consist of grading operations designed to improve overall site drainage. Grading operations will include filling of gullies and filling and revegetating areas disturbed by construction operations. An extensive fill will be constructed on the floodplain on the south bank of Brown's Wash using excess materials excavated for the disposal embankment.

Demobilization will primarily consist of removal and regrading of the wastewater retention basin and temporary drainage ditches. Contaminated water will be treated and discharged. Sediment and dike materials will be excavated and placed in the disposal embankment. The decontamination pad will be removed and placed in the disposal embankment. Associated equipment will be cleaned for salvage. The staging area will be dismantled. Associated contaminated items will be either buried or cleaned and salvaged. All contractor equipment will be decontaminated and inspected prior to release from contaminated areas.

4.6 CONSTRUCTION SCHEDULE

The remedial action includes the following tasks:

- o Mobilization.
- o Site preparation.
- o Placement of tailings.
- o Construction of embankment cover.
- o Construction of embankment erosion protection.
- o Site restoration.

Mobilization consists of bringing all required people and equipment to the site.

Site preparation includes establishing the site security system and construction office; the construction of the decontamination pad, retention basin, drainage ditches, and wastewater treatment facility; upgrading of haul and access roads; decontamination and demolition of existing mill buildings; and excavation and stockpiling of windblown contaminated soils.

Placement of tailings includes excavation of the below-grade portion of the disposal embankment, placement of the select fill layer, excavation and stockpiling of material from the tailings pile, and placement and compaction of the tailings and other contaminated materials in the disposal embankment.

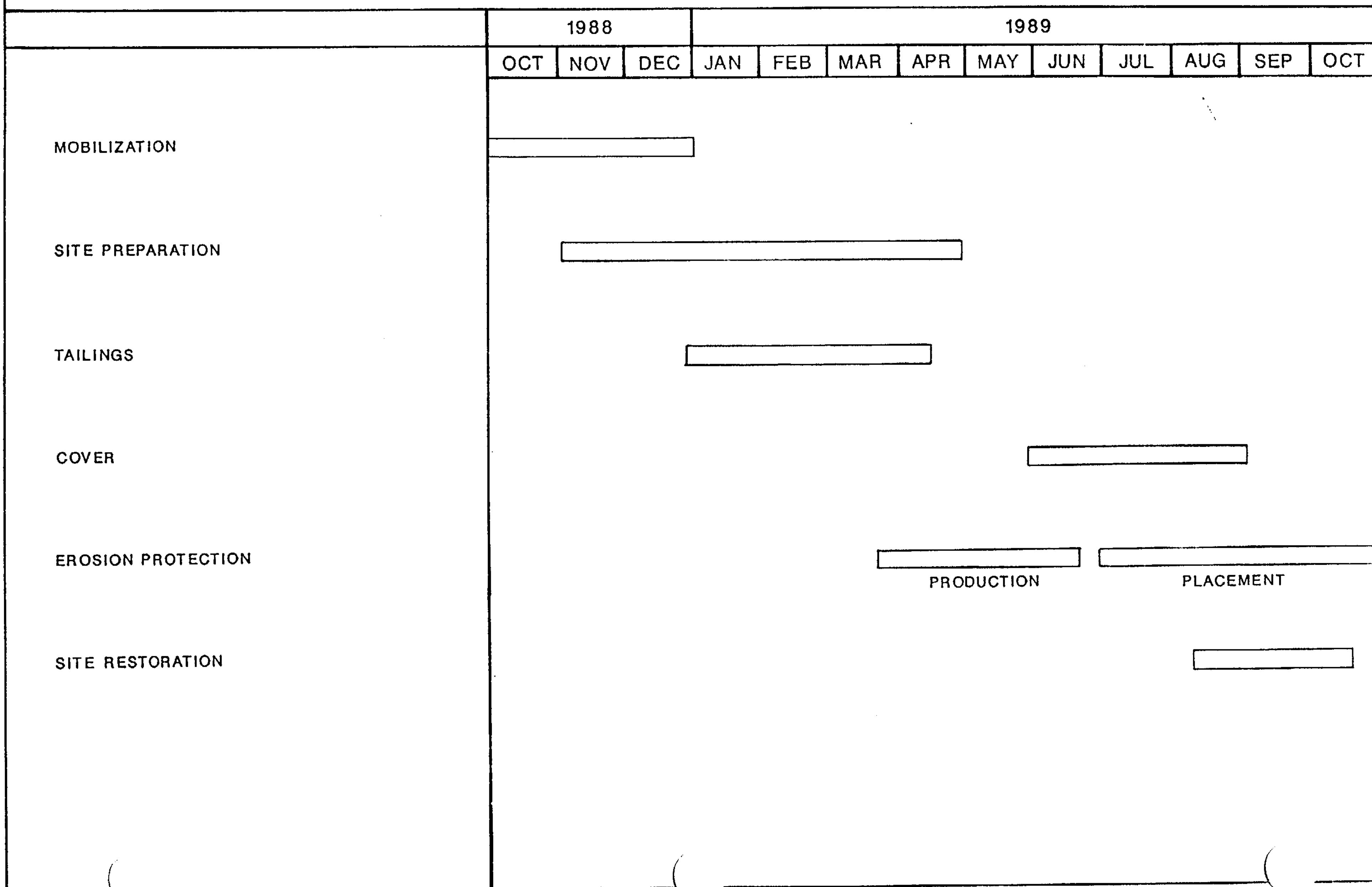
Construction of the embankment cover includes delivery to the site, placement in the embankment, and compaction of the infiltration/radon barrier and filter materials.

Construction of embankment erosion protection includes quarrying, delivery to the site, and placement of riprap materials.

Site restoration includes filling of existing gullies, removal of the retention basin and decontamination pad, regrading the floodplain of Brown's Wash, and reseeding of areas disturbed by construction, including borrow sites.

The timetable for performance of these tasks is presented on Figure 4.9. Construction operations are scheduled to start in September 1988, and are scheduled for completion in December 1989. A winter shutdown is optional, depending on weather conditions.

FIGURE 4.9 GREEN RIVER REMEDIAL ACTION SCHEDULE



5.0 WATER RESOURCES PROTECTION STRATEGY SUMMARY

The DOE must demonstrate compliance with the EPA standards for groundwater protection at inactive uranium mill tailings sites. These standards are contained in proposed revisions to Subparts A through C of 40 CFR 192 under Title I of the UMTRCA, as amended. Remedial action taken by the DOE must comply with the proposed standards until EPA promulgates them in final form (UMTRCA, Section 108). This section summarizes the water resources protection strategy for the Green River UMTRA Project site in Utah, and the elements of the strategy which demonstrate compliance with the proposed groundwater standards. Details of the water resources protection strategy are presented in Sections E.2 and E.3 of Appendix E. Characterization of groundwater and hydrogeology at the Green River site is presented in detail in Section D.5 of Appendix D, and is summarized in Section 3.5 of the text.

The DOE will comply with the disposal standard (40 CFR 192.02(a)(3)) by constructing a disposal cell that will prevent any tailings leachate from mixing with groundwater within the required 1000-year design life of the cell. Specifically, either designated MCLs or background concentrations (whichever is greater) will not be exceeded in the uppermost aquifer (the uppermost and lower-middle hydrostratigraphic units of the Cedar Mountain Formation) at the POC. The POC is the downgradient edges of the engineered disposal unit.

The following sections summarize the major elements of the protection strategy.

5.1 DESIGN CONSIDERATIONS

The tailings will be placed in a mostly below-grade cell. The base of the excavation will be at an elevation of about 4098 feet, which is nearly 40 feet below existing grade. Groundwater is 10 to 12 feet below the base of the excavation. The bottom six feet of the cell will be filled with a compacted, select clean fill soil to retard the movement of contaminants to groundwater from the overlying contaminated materials. Above the buffer will be a layer of compacted windblown tailings (mixed with clean soils) and a layer of compacted tailings.

A cover system will be constructed over the tailings. From bottom to top the cover system will consist of three feet of compacted radon barrier, six inches of clean, compacted bedding material, and one foot of rock for erosion protection. Collectively, the cover layers will limit infiltration of precipitation to less than 2×10^{-8} cubic centimeters per square centimeters per second (cm^3/cm^2s), will protect from catastrophic erosion by the PMF, and will control the release of radon from the cell. Degradation of the infiltration/radon barrier from freezing (via reduced density) will not occur because it is expected never to be saturated. Nevertheless, 15 inches of the infiltration radon barrier will lie beneath the calculated frost depth of 39 inches.

The disposal cell components (buffer, windblown materials, and tailings) will be placed at as low a moisture content as practicable, resulting in a flux rate of less than 2×10^{-8} cm^3/cm^2s, which is the saturated hydraulic conductivity of the infiltration/radon barrier multiplied by a unit gradient. By minimizing the amount of water used for compaction and dust control during construction, drainage of excess water from the cell is not a concern (see Section E.2.1.2).

In terms of groundwater protection, the proposed disposal cell and protection strategy at the Green River site make maximum use of the following favorable natural conditions:

- An arid climate (average annual precipitation is six inches per year; estimated ratio of yearly precipitation to actual evapotranspiration is one).

- Consistent, uniform fracturing of the foundation bedrock to prevent any perching of water in the cell and to promote drainage of runoff from the toe of the cell.

- Abundant, desirable secondary minerals on the fracture faces to attenuate any tailings seepage (although tailings seepage into the bedrock is not expected).

- Strong, upward vertical hydraulic gradients in the saturated bedrock downgradient of the disposal site to minimize the downward migration of contamination (although contamination of the groundwater by tailings seepage is not expected).

- Flow direction of groundwater beneath the disposal site toward the existing contamination from the old tailings pile.

In addition, the mostly below-grade disposal will maximize runoff and minimize infiltration into the disposal cell.

5.2 GROUNDWATER PROTECTION STANDARDS FOR DISPOSAL

There are three basic requirements for complying with the groundwater protection standard (40 CFR 192.02): (1) identification of the hazardous constituents within the disposal cell; (2) proposal of a concentration limit for each hazardous constituent; and (3) specification of the point of compliance.

Ten hazardous constituents (from Appendix IX of 40 CFR 264) within the tailings at the Green River site were identified from analyses of tailings pore water. These are cadmium, chromium, molybdenum, nickel, nitrate, selenium, uranium, vanadium, radium-226 and -228, and gross alpha activity. The proposed concentration limits for the ten hazardous constituents are listed in Table 5.1 along with the NRC's proposed interim concentration limits for hazardous constituents at the disposal site. Also, three additional hazardous constituents were included in DOE's and NRC's list of constituents for the disposal unit. These constituents are arsenic, lead, and methylene chloride.

Table 5.1 Hazardous constituents and concentration limits for disposal at the Green River UMTRA Project site[a]

Constituent	DOE proposed limits	Interim concentration limits
Arsenic	-	0.05 (MCL)
Cadmium	0.01 (MCL)	0.01 (MCL)
Chromium	0.09 (Background)	0.05 (MCL)
Lead	-	0.05 (MCL)
Methylene chloride	-	0.005 (Background)
Molybdenum	0.24 (Background)	0.1 (MCL)
Nickel	0.09 (Background)	0.06 (Background)
Nitrate	180 (Background)	60 (Background)
Selenium	2.50 (Background)	0.66 (Background)
Uranium-234/238	0.146 (Background)	0.044 (MCL)
Vanadium pentoxide	0.38 (Background)	0.09 (Background)
Radium-226/228	5.0 pCi/l (MCL)	5.0 pCi (MCL)
Gross alpha (excluding uranium and radon)	195 pCi/l (Background)	24.5 pCi/l (Background)

[a]All concentrations are milligrams per liter (mg/l) unless noted otherwise; pCi/l = picocuries per liter.

The proposed concentration limits have associated with them a natural variability. This natural variability must be accounted for when sampling and analyzing for construction and performance monitoring and in an assessment of what threshold concentration constitutes an excursion and warrants subsequent corrective action. The details of such an analysis will be presented in a separate document (Surveillance and Maintenance (S&M) Plan) for the Green River site.

The point of compliance at the Green River site will be the entire northwest and northeast edges of the engineered cell. Approximately 60 feet of rock riprap and select fill material lie between the compacted tailings and the point of compliance.

5.3 PERFORMANCE ASSESSMENT

The proposed disposal cell design is intended to prevent the introduction of contaminants into groundwater by providing for leachate travel times from the base of the contaminated soil to groundwater in excess of the design life (1000 years) of the cell.

The NRC UNSAT2 computer model (NRC, 1983) was used to estimate the redistribution of moisture within the disposal cell with time. Examination of the moisture distribution with time allows conclusions to be drawn regarding the steady state moisture conditions within the disposal cell, the travel time of contaminants through the disposal cell, and the flux at the bottom of the disposal cell. Based on the modeling, the travel time for contaminants exiting the bottom of the disposal cell is over 1100 years. (A more detailed discussion of the disposal cell performance is presented in Section E.3.2.) Because leachate percolating from the disposal cell is not expected to reach groundwater within the design life of the cell, no degradation of groundwater quality as a result of the remedial action is anticipated.

5.4 CLOSURE PERFORMANCE ASSESSMENT

The DOE must demonstrate compliance with the closure performance standard (40 CFR 192.02(a)(4)) by showing that the need for further maintenance of the disposal site and cell has been minimized and that the disposal unit minimizes or eliminates releases of hazardous constituents to groundwater.

Natural, durable materials will be used to construct the cell so that long-term performance is assured. Safety factors have been considered in the design so that the cell should operate for longer than the required 1000-year design life.

The previous section (5.3) discussed how the disposal cell will eliminate the release of hazardous constituents to groundwater at the Green River site.

5.5 GROUNDWATER PERFORMANCE MONITORING PROGRAM

The DOE is required to describe an integrated monitoring program to be conducted before, during, and after completion of the remedial action to demonstrate that the initial performance of the cell complies with the groundwater protection standard and the closure performance standards.

The DOE will present a detailed groundwater monitoring program in the S&M Plan for the Green River site. The main features of the monitoring program will include moisture monitoring in the tailings, windblown material and buffer layers, and saturated zone monitoring at the point of compliance. There is nothing that would physically preclude this program from being implemented.

Four neutron access holes for neutron logging will be used to monitor moisture within the tailings, vicinity property materials, other contaminated material, and buffer materials at different depths. The time-integrated moisture versus depth data will be used to estimate the unsaturated hydraulic conductivity of the tailings and the operative flux of moisture through the cell.

The compliance monitor wells will be sampled quarterly during the first year following completion of the remedial action, semi-annually for years two through six, and annually thereafter until the end of the performance monitoring period. Monitoring during the remedial action will take place semi-annually using wells placed during site characterization. The constituents to be analyzed from monitor well samples shall include all of the hazardous constituents presented in Section E.1.2 plus major anions and cations together with the standard suite of field parameters (alkalinity, pH, temperature, and specific conductance).

5.6 CORRECTIVE ACTION PLAN

The DOE is required to evaluate alternative corrective actions that could be implemented if the disposal monitoring program indicates that the disposal cell is not performing adequately (40 CFR 192.02(c)). The DOE should consider reasonable failure scenarios of the disposal cell and demonstrate that corrective actions could be implemented no later than 18 months after finding an exceedance of the groundwater protection standards.

The DOE has demonstrated that the disposal cell at Green River has been designed (and will be constructed) to perform for the mandated design life of 1000 years (see Section E.2.2.2). The design has incorporated standard safety factors and should therefore perform for at least 1000 years with minimal maintenance. There is therefore no "reasonable" failure scenario which would be related to catastrophic structural failure.

A potential "failure" of the cover system, in terms of groundwater protection, would be if the infiltration/radon barrier was not limiting infiltration to the design flux rate of 2×10^{-8} cm^3/cm^2s. The best-case corrective action for this condition at Green River would be first to assess the potential impacts to groundwater at the higher flux rate, and then to assess the risks to human health and the environment should there be a potential impact. A preliminary risk assessment conducted for the Green River site (DOE, 1988c) indicated minimal pathways for exposure for the potentially affected aquifers because of already poor quality groundwater within the aquifers. It is unlikely that any corrective action would be required at the Green River site such as reconstructing the cover system or active restoration of the affected aquifer(s) because of minimal risk to human health or the environment. To finalize the preliminary risk assessment to include a specific failure scenario would take only a few months; this plus any other necessary corrective action (applying for ACLs for any hazardous constituents predicted to exceed the proposed concentrations limits) could easily be done within the 18-month action time frame. The worst-case corrective action scenario would require removal and replacement of the cover and possible groundwater cleanup.

An exceedance of the proposed concentration limit for any hazardous constituent at the point of compliance (as determined from saturated zone monitoring during the early stages of performance monitoring) would likely be a result of drainage of construction water. This would be verified by examining the moisture monitoring system to be sure that excess moisture is not passing through the cell. Since every effort will be made during construction of the cell to limit the amount of water added for compaction (per specific construction specifications) and dust suppression, an excursion at the point of compliance is considered highly unlikely, particularly when travel time of any contaminants through the bottom six feet of buffer (and foundation bedrock) is considered. Any excursion at the point of compliance detected by saturated zone monitoring would include resampling and analysis at least once to verify the excursion. Details of these procedures will be presented in the S&M Plan for the Green River site.

5.7 CLEANUP AND CONTROL OF EXISTING CONTAMINATION

The DOE and NRC consider that evaluation of cleanup of existing groundwater contamination (Subpart B of 40 CFR 192) at the Green River processing site should be deferred until after the EPA promulgates final groundwater protection standards, provided the DOE demonstrates that disposal may proceed independently of cleanup (Subpart B of the standards can be "decoupled" from Subpart A).

By defining existing and background water quality at both the processing and disposal sites, the DOE has demonstrated that the present water quality is distinguishable from any adverse impacts that may result from the remedial action. In addition, construction of the disposal cell will in no way preclude any future aquifer restoration activities from taking place, should active restoration be deemed necessary. Finally, because the period of construction is relatively short at Green River and the extent of existing contamination is almost entirely within the site boundaries, there is very little or no risk that human health or the environment could be impacted by leaving the contamination in place during the interim period between remedial action and evaluation of groundwater cleanup.

There are several methods of restoring the affected aquifers at the Green River processing site if it ever becomes necessary to do so. Because the source of contamination will be removed when the tailings are placed and stabilized at the disposal site, and background quality of groundwater in the affected aquifers is poor, the most appropriate method of restoring the aquifers is probably to allow the contamination to flush naturally and disperse downgradient from the site. Natural flushing may be used as the sole method for restoration, or it may be used in conjunction with any of a number of active restoration methods.

6.0 ENVIRONMENTAL, HEALTH, AND SAFETY

6.1 POLICY

It is the policy of the UMTRA Project that the DOE and its contractors take all reasonable precautions in the performance of the remedial action work to protect the environment, ensure the health and safety of employees and the public, and provide protection of the U.S. Government. The DOE and its contractors will comply with all applicable Federal and state health and safety regulations and requirements including, but not limited to, those required by the Occupational Safety and Health Administration (OSHA).

The RAC will have the principal responsibility for implementing a health and safety program. The program should include an on-site professional radiation health staff responsible for implementing monitoring, sampling, training, and reporting procedures. The surrounding community and the on-site workers must be protected to prevent avoidable accidents and radiation exposure. The RAC will follow the "UMTRA Project Environmental, Health, and Safety Plan" (DOE, 1985) and additional site-specific guidance, such as that in the Special Conditions of the subcontract documents.

6.2 SITE CONDITIONS AFFECTING HEALTH AND SAFETY PLANNING

Health and safety considerations at the Green River site will require special attention by the RAC because of the physical, radiological, and industrial hygiene hazards that may exist there. This section describes the specific conditions that represent potential hazards that are known or suspected to exist. The following text is not intended to provide a comprehensive list of potential hazards, but rather describes conditions that have been noted during prior work activities at the Green River site.

Appendix D, Site Characterization, contains a description and map of the existing utilities at the Green River site. Buried gas, water and sewer lines, and above-ground electric lines exist on and around the processing site. In addition, there is a propane tank buried near the mill yard, and unmarked lines that were part of the original mill operations may be buried around the site and near the mill buildings.

Four main buildings, several small buildings, and a water tower remain at the site. The buildings are abandoned, and all structures are considered structurally sound but in a state of disrepair. Processing chemicals have not been observed during previous site visits, but may still be stored in some of the abandoned buildings. Radiological contamination and external exposure rates have been measured in the buildings and the results are reported in Addendum D1 to Appendix D, Site Characterization.

The processing site is located approximately one mile southeast of the city of Green River, Utah. Highway traffic may be heavy along I-70, south of the site, and along the main line track of the Denver and Rio Grande Western Railroad, which runs to the north. Both represent potential vehicle hazards and should be considered in planning the remedial actions, and in developing employee orientation and safety training programs.

The Green River runs near the western site boundary, and an intermittent tributary to Green River, Brown's Wash, runs north of the site. In the past, floodwaters have carried an estimated 14,000 tons of tailings downstream (FBDU, 1981). Potential hazards due to flooding should be considered and appropriate contingency plans should be prepared.

Some emergency response facilities exist in the city of Green River, and may be easily accessed by telephone. Emergency phone numbers are:

Fire/Ambulance/Medical Clinic	8111
Police/Sheriff	8111 or 564-3431

The Green River Medical Clinic is located at 110 South Medical St., and has no full-time doctor. The nearest hospital with an emergency room is 60 miles away in Moab, Utah. Helicopter ambulance service is available by calling the 8111 emergency number.

7.0 RESPONSIBILITIES OF PROJECT PARTICIPANTS

7.1 INTRODUCTION

The following defines the various responsibilities of the DOE UMTRA Project Office, the NRC, and the state of Utah during design, remedial action, and through the initiation of custodial surveillance and maintenance. The DOE will be assisted by its Technical Assistance Contractor (TAC), the Jacobs-Weston Team and its RAC, M-K Ferguson Company, Inc.; however, all assigned responsibilities will remain the ultimate responsibility of the DOE. In general, the TAC will assist the DOE in the preparation of conceptual designs and remedial action plans and will provide quality assurance, audits, and recommendations for final certification. The RAC will prepare detailed designs and manage field construction activities. The state of Utah's responsibilities will be administered and coordinated by the Utah Department of Health.

Major areas of responsibility for future actions by the DOE, the state of Utah, and the NRC are summarized as follows:

- <u>DOE (including TAC, RAC)</u>:

  Prepare the RAP.
  Manage and coordinate project.
  Obtain permits and approvals.
  Prepare detailed designs and specifications.
  Prepare quality assurance plan.
  Prepare and implement public participation and information plan.
  Provide funds.
  Conduct remedial action.
  Audit remedial action.
  Prepare surveillance and maintenance plan.
  Certify remedial action.
  Obtain license.
  Conduct surveillance and maintenance.

- <u>State of Utah</u>:

  Review and concur in the RAP.
  Assist DOE in acquiring or extinguishing the interests of land owners or others with property interests at the designated processing site and disposal site.
  Assist in obtaining local government approvals.
  Issue state permits or approvals.
  Assist in public participation and information.
  Convey to the Federal government title to residual radioactive materials stabilized at the site.
  Provide funds.

o NRC:

Review and concur in the RAP.
Review and concur in the Remedial Action Inspection Plan (RAIP).
Review and concur in surveillance and maintenance plan.
Review and concur in final certification report.
Issue license for long-term surveillance and maintenance of the disposal site.

7.2 DETAILED RESPONSIBILITIES

Detailed responsibilities of the project participants in the areas of regulatory compliance, licensing, land, detailed design, construction, health and safety, public information, radiological support, quality assurance, and custodial surveillance and maintenance are defined in the following sections.

7.2.1 Regulatory compliance

Requirements for regulatory compliance, previously identified by Federal and state agencies, will be incorporated into the final design specifications, as needed, by the DOE. Revisions to the design and specifications resulting from internal DOE reviews will be incorporated prior to the agencies' review for permits.

The RAC will submit permit applications and supporting details to the agencies for permit issuance.

During the remedial action, the DOE will audit construction activities for compliance with provisions in the permits and approvals. (Permitting agencies may independently audit relevant activities consistent with normal practice.) Summary audit reports will be prepared by the DOE and submitted to the appropriate agencies as required. Depending upon agency comments, revisions to construction compliance activities will be made.

Upon completion of the permitted action, the DOE will conduct a final review and will prepare a close-out report for submittal to the agencies as required. Permits will then be terminated.

7.2.2 Licensing

The NRC will issue a general license for post-remedial maintenance of Title I sites by amendment to 10 CFR 40. The NRC's concurrence in the site-specific S&M Plan will render the site licensed. A draft site S&M Plan will be submitted to the NRC prior to certification. Based on the NRC comments, a final S&M Plan will be prepared and submitted to the NRC. The final plan will contain the site-specific surveillance and maintenance program, legal description of the site, site ownership, subsurface mineral ownership, and reporting and record keeping requirements.

7.2.3 Land acquisition

The state of Utah will assist the DOE in acquiring or extinguishing the interests of landowners, permittees, lessees, and sublessees of, or other individuals with property interests in the processing and disposal sites. Upon completion of the remedial action, legal title to the disposal site and attendant residual radioactive materials will be conveyed to the Federal government.

7.2.4 Detailed design

The RAC will prepare preliminary engineering drawings for review by the DOE. Based upon this review, the RAC will prepare final design drawings, specifications, and bid packages. Once finalized and approved by the DOE, the bid packages will be issued to prospective bidders pursuant to Federal regulations and a construction subcontractor(s) will be selected.

Final design and specifications will be available to the NRC and the state upon request, and will be included in the final RAP.

7.2.5 Construction

The DOE will prepare guideline documents to comply with health and safety, security, quality assurance, public information, and other regulatory requirements. The RAC will acquire the necessary permits and approvals from the appropriate agencies. Site mobilization and initiation of construction activities will occur in accordance with the DOE-approved construction schedule.

Construction activity will be audited by the DOE. These audits will be provided to the NRC and the state of Utah, and to other regulatory agencies upon request to the DOE. The state, NRC, and other regulatory agencies may also perform independent audits of the remedial action. Revisions to the remedial action resulting from site audits will be incorporated into the as-built design and the RAP by the DOE as necessary.

Upon completion of the remedial action, the site will be certified by the DOE. The NRC will review and concur in the final site certification report.

7.2.6 Health and safety

The DOE has prepared the "UMTRA Project Environmental, Health, and Safety Plan" (DOE, 1985). Based upon this guidance, site-specific implementation procedures will be developed by the RAC.

As part of the implementation procedures, the RAC will institute radiation control and environmental monitoring and will develop response procedures for severe weather and medical emergencies.

Construction contractors will comply with approved procedures and file reports with the DOE that record the results of monitoring, and report accidents and illnesses. Records will be maintained by the DOE following remedial action construction. Employee and public complaints will be investigated by the DOE.

7.2.7 Public information

The DOE will establish a local site manager who will provide information to the public and local media. Prior to and during construction, the DOE, with assistance from the state of Utah officials and local citizens, will conduct public information meetings to inform the interested public of key aspects and current progress of the remedial action. Concurrent with the public meetings, the DOE will provide status and progress reports for the state of Utah and other agencies (e.g., the NRC and EPA).

7.2.8 Radiological support

The DOE will prepare and implement a Radiological Support Plan (Appendix C) and will take measures to independently assure the quality of the analyses and compliance with the procedures.

After remedial action, the DOE will prepare a completion report, conduct a final verification survey, and provide a recommendation for site certification. The NRC will concur in the final site certification report.

7.2.9 Quality assurance

The DOE will prepare the Quality Assurance (QA) plan in conformance with guidelines established in the UMTRA Project QA plan (DOE, 1986b). The DOE will audit the construction activities and will submit audit reports as appropriate.

7.2.10 Surveillance and maintenance

The DOE will prepare and submit to the NRC the S&M Plan as part of the site license application. The NRC will review and concur with the plan, and the DOE (or responsible Federal agency designated) will ensure that the plan is implemented.

8.0 SURVEILLANCE AND MAINTENANCE

8.1 INTRODUCTION

The objectives of the custodial surveillance and maintenance program are to assure that, upon completion of remedial action, the stabilized embankment remains undisturbed, the tailings continue to be non-hazardous to the public and the local environment, and all site conditions comply with the EPA, NRC, and state of Utah standards.

The custodial surveillance and maintenance program will be defined jointly by the DOE and the NRC during the creation of the proposed S&M Plan and concurrence. Following are the basic elements that may be included in this program.

8.2 SURVEILLANCE

8.2.1 Site inspections

Site inspections constitute visual and definitive verification that the disposal site continues to function as designed and assures continued compliance with regulatory standards. Inspections will consist of two phases: Phase I, a systematic walk-over designed to evaluate the condition of the disposal site qualitatively; and, if needed, Phase II investigations to assess quantitatively changes in the disposal site that could lead to functional failure of the design in the absence of custodial maintenance.

The Phase I inspection will be conducted on a specific schedule, such as annually, by a team of qualified professionals. The inspection team will review as-built drawings, engineering details, aerial photographs, and supporting documentation. A site walk-over will then be performed to evaluate any changes at the site with regard to factors such as erosion, flood effects, slope/cover stability, settlement, displacement, plant or animal intrusion, and access control.

Based upon the evaluation and recommendations of the inspection team, Phase II evaluations may be conducted to determine the magnitude and rate of changes in the above factors quantitatively. From these studies, the need for corrective action (i.e., custodial maintenance) would be ascertained.

8.2.2 Aerial photographs

Aerial photographs will be used to supplement site inspections. The objectives will be to identify changes in site conditions (e.g., patterns of developing erosion that may affect the function of the design), provide visual documentation of long-term variation in site conditions, and identify activities (e.g., road conditions, storm drainage construction) adjacent to the site that may affect its function.

Aerial photographs may also be taken on a periodic schedule. Photographs will be taken at both low (i.e., high resolution) and high (i.e., for adjacent activities) altitudes and at oblique and vertical angles. The type of film, ground control, camera specifications, amount of overlap, interpretative keys, and other requirements will be established as part of the custodial surveillance and maintenance program.

8.2.3 Groundwater monitoring

Long-term, post-remedial-action monitoring of the uppermost downgradient aquifer will be conducted at the disposal site. Monitoring is outlined in Section E.3.4 of Appendix E and will be described in detail in the site S&M Plan.

8.2.4 Reporting

Summary surveillance and monitoring reports that evaluate the results of these activities and recommend needed custodial maintenance (i.e., corrective actions), along with future surveillance and monitoring, will be prepared. Reports and supporting documentation will be placed on file with the DOE, NRC, and the state.

8.3 CUSTODIAL MAINTENANCE

The need for custodial maintenance can only be determined following site inspection. However, it is anticipated that custodial maintenance will consist primarily of the following:

- o Limited soil/rock replacement due to unanticipated erosion, human or animal intrusion, or cover disturbance--these activities are expected to be required infrequently.
- o Control of deep-rooted plants by infrequent application of herbicides or physical removal as required.
- o Mechanical repairs to security fence, gates and locks, and warning signs, when necessary.

8.4 CONTINGENCY PLANS

Procedures will be developed to inspect and perform maintenance, as required, of the disposal site upon the occurrence of severe meteorological events (e.g., extreme rainfall), seismic events in excess of design parameters, or unusual human intrusion.

9.0 QUALITY ASSURANCE

9.1 GENERAL

The RAC shall provide and maintain an effective QA program and procedural system which will assure that all work, materials, supplies, and services required under the contract conform to contract requirements, whether constructed or processed by the RAC or its subcontractors or procured by subcontractors or vendors. The RAC shall perform or have performed adequate inspections and tests as will ensure and substantiate that all work, materials, supplies, and services conform to contract requirements.

The RAC shall furnish a QA test and inspection plan that will define the health, safety, and environmental activities to be incorporated into the design and/or performed during construction to ensure contract compliance and site certification. Test and inspection requirements shall be approved by the DOE prior to the start of any job site construction work under this contract. If the RAC revises the plan, the RAC shall concurrently furnish a copy of the revision to the DOE for approval prior to implementing the revision on work under the contract.

9.2 QUALITY ASSURANCE PLAN

Before construction operations are started, the RAC shall meet with the authorized DOE QA representative to review and discuss the RAC's proposed project QA plan. The meeting shall clarify details of the individual site plan requirements including the formats to be used for recording and reporting tests and inspections, administration of the plan, personnel assignments, and the interrelationship between the RAC and the DOE QA representative. The RAC shall furnish a list of the procedures required to implement the project plan. This list shall include, at a minimum, procedures for data collection, analyzing samples, inspection and testing, and formats of reports to be used.

9.3 DAILY INSPECTION REPORT

The RAC shall prepare a daily report for every day worked, and a weekly summary report covering the RAC and subcontractor's operations in an appropriate format. The daily reports shall provide complete and factual evidence that continuous, effective quality control inspections and tests have been performed, including but not limited to: (1) the type and number of inspections and tests involved; (2) results of inspections and tests; (3) nature of deficiencies requiring corrections; and (4) corrective actions taken or to be taken.

The RAC shall maintain current records of all inspections and shall furnish, as part of the files at the end of the project, copies of the inspection reports and all other files appropriate to each subcontract. The reports of inspection shall cover all work placement subsequent to the previous report and shall be verified by the RAC's designated QA representative.

9.4 MEASURING AND TEST EQUIPMENT CALIBRATION AND CONTROL

The RAC shall provide measuring and test equipment having the precision and accuracy needed to establish conformance with specified quality requirements. Calibrations shall be in accordance with nationally recognized standards. The RAC shall identify procedural systems for test equipment calibration and recall.

9.5 NONCONFORMANCE

A nonconformance and change procedural system shall be developed by the RAC and approved by the DOE.

9.6 RECORDS CONTROL

The RAC shall be responsible for generation, retention, and retrieval of legible records that provide objective evidence of conformance to the specified quality requirements. These records shall be considered valid only if they are completed and signed or otherwise authenticated and dated by authorized personnel. These records shall include, but are not limited to:

- Radionuclides in soil data.
- Air monitoring data.
- Design review files.
- Water contaminant analysis.
- Personnel radiation exposure data.
- As-built drawings.
- Test and inspection reports.
- Engineering specifications.
- Material certifications.
- Certificates of compliance.
- Non-conformance reports and corrective action requests.
- Operating procedures.
- Change orders.
- Unusual occurrence reports.

All records shall be available to the DOE for review upon request. All personnel radiation exposure records shall be turned over to DOE upon completion of the site remedial action.

9.7 CODES AND STANDARDS

The RAC shall have on the job site, no later than three weeks after site mobilization, the applicable quality assurance codes and standards available for ready reference by all personnel. The RAC shall maintain at the job site copies of all approved-for-construction drawings, specifications, and other documents which describe the remedial action.

9.8 RECORD DRAWINGS

The RAC shall develop QA procedural systems to ensure the use of approved-for-construction drawings and updating of record drawings. Two full-sized sets of contract drawings shall be used by the RAC for this purpose. All variations from the contract drawings shall be depicted. Generally, the drawings shall reflect only changes and corrections to data and dimensions shown on contract drawings. Where the contract specifications or drawings permit optional use of more than one type of material or equipment, the type of material or equipment installed shall be shown on the drawings. The drawings shall be maintained in a current condition at all times, and shall be made available for review by the DOE at all times. Variations from the contract drawings shall be shown in the contract working drawings and shall be incorporated into the record drawings. Upon physical completion of the contract work, two reproducible copies of these drawings shall be furnished to the DOE.

9.9 MATERIAL CERTIFICATION

The technical specifications may require that certain materials be certified. Two types of certifications that may be specified are:

- Certificate of compliance.

- Certified material test report (CMTR). When a CMTR is requested from the RAC or its subcontractors, it shall be accompanied by a certificate of compliance certifying that the tested material is actually the material incorporated in the work.

9.10 QUALITY ASSURANCE PROGRAM VERIFICATION

Verification of the QA program implementation by DOE may be accomplished by:

- Review of daily or weekly summary reports.
- On-site inspections and surveillance.
- Periodic audits.
- Acceptance of DOE QA recommendations based on DOE QA audits of RAC activities.
- Any combination of the above.

9.11 REMEDIAL ACTION FIELD CHANGES

During the course of remedial action, design changes are expected to occur. Some of these changes may impact compliance with EPA standards, but most changes are expected to be unrelated to critical design elements of the stabilized tailings pile. The following sections define three classes of changes and establish guidelines to be used when implementing changes.

9.11.1 Class 1 changes

A Class 1 change is a change that may affect compliance with the EPA standards (40 CFR 192). Class 1 changes shall be reflected in a modification to the RAP, which will ultimately result in a change to the State Cooperative Agreement. The NRC and the state of Utah will be required to concur on all Class 1 changes.

Class 1 changes include, but are not limited to, the following:

- Discovery of unusually high levels of residual radioactive materials which will change the radon emission concentrations after remedial action as they are specified in the final RAP.
- Disposal of hazardous or mixed wastes within the disposal cell.
- Changes in the radon barrier thickness or permanent erosion protection.

9.11.2 Class 2 changes

A Class 2 change is a change to any permanent construction feature that does not clearly affect compliance with the EPA standards. Class 2 changes will be forwarded to the NRC and the state of Utah for informative purposes. At any time that the NRC and/or state feel a change has been incorrectly designated as Class 2, the change may be redesignated as Class 1 upon verification of error. By handling Class 2 changes in such a manner, construction delays will be avoided, and the NRC and state will consistently be aware of all changes affecting the RAP. Class 2 changes will not require formal NRC or state concurrence, and will not require a modification to the RAP or Cooperative Agreement.

Class 2 changes include, but are not limited to, the following:

- Adjustments to specifications that will not affect the major aspects of design, such as permeability, infiltration, radon flux, or groundwater contamination.
- Requests for additional well sealing for newly discovered wells.
- Changes in location of permanent fencing.

9.11.3 Class 3 changes

A Class 3 change is a change to temporary features that have no impact on the design for the stabilization of the stabilized embankment. Class 3 changes will not require NRC or state concurrence and may be approved by a representative of the Remedial Action Contractor of appropriate supervisory position.

Class 3 changes include, but are not limited to, the following:

- o Changes in location or use of construction/excavation materials.
- o Change in location of temporary fencing.
- o Alteration of temporary drainage facilities, roads, or site office facilities.

9.11.4 General requirements

The general requirements which are to be fully understood and commonly interpreted by all parties (DOE, NRC, state) when using the above classification of changes are as follows:

- o All changes will be logged on a Project Interface Document (PID), which will be initiated by the RAC and forwarded to the DOE Project Office (PO). The DOE PO will then forward copies of the PID and supporting data, if required, to the NRC and the affected state as outlined below.
- o Each change will be classified promptly by the RAC and concurred upon by the DOE Project Office, with input from the TAC if needed, immediately following notification from the field. The contact for DOE concurrence shall be documented in the space provided on the PID.
- o For all Class 1 changes, the DOE will notify the NRC and state no later than one working day after notification by the RAC. The NRC and the state will then be given copies of all pertinent data necessary for review and concurrence or comment within one working day after receipt of same by the DOE PO. This may be transmitted verbally or telefaxed prior to formal issuance.
- o RAP modifications may be handled as a group as opposed to separate issuance each Class 1 change.
- o For all Class 2 changes, appropriate justification data will be forwarded to the NRC and state as submitted to the DOE PO by the RAC. This may be transmitted following verbal or telefaxed notification as noted under the third

general requirement above. Written justification will be forwarded by the PO within five working days after receipt.

- For all Class 3 changes, the PID will be forwarded to the NRC and the affected state within a reasonable time.

- The RAC will maintain an up-to-date record of all changes for all sites. In addition, the DOE PO will maintain an up-to-date file of all PIDs.

10.0 PUBLIC INFORMATION AND PUBLIC PARTICIPATION

10.1 INTRODUCTION

Section III of the UMTRCA states,

> "In carrying out the provisions of this title, including the designation of processing sites, establishing priorities for such sites, the selection of remedial action and the execution of cooperative agreements, the Secretary (of Energy), the Administrator (of the Environmental Protection Agency), and the (Nuclear Regulatory) Commission shall encourage public participation and, where appropriate, the Secretary shall hold public hearings relative to such matters in the state where processing sites and disposal sites are located."

The following sections describe the actions the DOE and state have taken and will take to encourage the participation of an informed public in this project.

10.2 PUBLIC PARTICIPATION

The National Environmental Policy Act (NEPA) of 1969 requires an evaluation of the environmental impacts of major Federal actions that may significantly affect the environment. Before remedial action construction can begin, an Environmental Assessment (EA) will be completed for the Green River site. Public participation is an important part of the preparation of the EA; the participation requirements are detailed in the Council on Environmental Quality Regulations (effective July 1979) for implementing the provisions of NEPA, and in the DOE guidelines of 1980 for NEPA compliance.

In preparing the EA, the DOE has conducted individual meetings with community officials and private citizens to discuss the purpose of the proposed remedial action and ascertain the extent of public interest in this project. At these meetings, the public is given an opportunity to express their concerns and identify what they believe to be significant issues.

The identified issues are documented in the EA and incorporated into the decision-making process. The DOE accepts written comments for a 30-day period after publication of the EA. Interested parties are given the opportunity to comment on the EA after the EA is published.

In addition to meetings on the EA, the DOE will continue to hold public information meetings in Green River to describe the remedial action plan for the project and receive comments which may be used in the design for remedial action.

A Task Force comprised of local citizens will be formed if needed to serve as a major communication link in the decision-making process and to meet with the DOE and state to convey community response to project activities. The Task Force should continue to meet periodically throughout the duration of remedial action construction.

Frequent meetings and briefings will be held to provide information and project status updates, and to solicit public participation in the project activities. The DOE, state and local officials, and interested citizens are involved in discussions regarding remedial action construction schedules, radiation monitoring reports, groundwater protection plans, and other project activities.

10.3 PUBLIC INFORMATION

In order for public participation to be effective, the public must be informed concerning the remedial action project in Green River. Several methods of information dissemination are used by the DOE. Press releases and press packets are prepared for project status updates, including report summaries, texts of presentations, and graphics.

The names and addresses of individuals, media representatives, and Federal, state, and local officials are computerized for information dissemination purposes. Information is provided to interested persons in the Federal government, state administration, and private citizens in Grand County.

A public preconstruction meeting will be conducted by the DOE. Principal topics of discussion include the remedial action design and construction schedules.

An on-site representative will be designated by the DOE to respond to public inquiries during remedial action construction. This representative will work closely with the DOE to provide information and meet frequently with the public throughout the construction period.

A variety of printed materials will be prepared concerning the UMTRA Project and the Green River site. These include project fact sheets, a site fact sheet, and the EA. As they are printed, these materials and other fact sheets and documents have been and will continue to be sent to interested individuals and are available in the public libraries, county offices, and the Utah Department of Health. The same materials are also available at DOE-designated libraries nationwide.

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GLOSSARY

absorbed dose, radiation	The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material at the point of interest; usually given in units of "rads."
alluvium	Sediment deposited by a flowing river.
ambient	Surrounding on all sides, encompassing.
anticline	A fold in rocks that is convex upward or had such an attitude at some stage of development.
aquifer	A subsurface formation containing sufficiently saturated permeable material to yield usable quantities of water.
aquitard	A saturated geologic unit that does not transmit usable quantities of water.
attenuate	To reduce in strength, force, value, or amount.
background radiation	Background radiation due to cosmic rays and natural radioactivity is always present. Background radiation may also be present due to the presence of radioactive substances in building materials, and the like.
bioassay	A method for quantitatively determining the concentration of radionuclides in a body by measuring the quantities of those radionuclides that are eliminated from the body, usually in the urine or the feces.
Class III archaeological surveys	Relates to an archaeological investigation of probable occurrence of cultural resources within a given locale. A Class III survey is an in-depth inspection of an area to determine the presence of archaeological materials where the likelihood of their occurrence is high, based on the history of the area.
concentration, maximum permissible	The maximum concentration of radionuclide that a remedial action worker may be exposed to which, if accumulated during a set time interval, would be within Federal safety standards.
confined aquifer	An aquifer bounded above and possibly below, by continuous beds or strata of much lower permeability. In general, a confined aquifer contains water under pressure that is significantly greater, or less than, the normal hydrostatic pressure gradient of water created by the force of gravity.
contamination	In this report, the presence of radioactive material in concentrations above natural levels.
cosmic rays, radiation	High energy particulate and electromagnetic radiations that originate outside the earth's atmosphere.

curie (Ci) — The unit of radioactivity of any nuclide, defined as precisely equal to 3.7×10^{10} disintegrations per second.

daughter product(s) — A nuclide resulting from radioactive disintegration of a radionuclide, formed either directly or as a result of successive transformations in a radioactive series; it may be either radioactive or stable.

decay chain, radioactive — A succession of nuclides, each of which transforms by radioactive disintegration into the next until a stable nuclide results.

decay, radioactive — Disintegration of the nucleus of an unstable nuclide by spontaneous emission of charged particles, photons, or both.

decontamination — The reduction of radioactive contamination from an area to a predetermined level set by a standards-setting body such as the EPA by removing the contaminated material.

disposal — The planned, safe, permanent placement of radioactive waste.

dose — A general term denoting the quantity of radiation or energy absorbed, usually by a person; for special purposes, it must be qualified; if unqualified, it refers to absorbed dose.

dose, absorbed — The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material at the point of interest; given in units of rads.

dose equivalent — The quantity that expresses all kinds of radiation on a common scale for calculating the effective absorbed dose and defined as the product of the absorbed dose in rads and modifying factors, especially the quality factor; usually given in units of rems; often abbreviated "dose."

dose equivalent, committed — The dose equivalent to organs or other tissues that will be received following an intake of radioactive material during the 50-year period following that intake.

dose equivalent, committed effective — The weighted sum of committed dose equivalents to organs using weighting factors based on the susceptibility of each organ to certain health factors.

dosimetry — The determination of radiation doses, by measurement or calculation.

effective porosity — The percent of a total volume of a given mass of soil or rock that consists of interconnecting interstices.

eolian — Deposited after transport by wind.

equilibrium (radioactive)	In a radioactive decay chain, the state when the ratios between activities of successive members of the decay chain remain constant.
exposure	A measurement of the amount of gamma radiation that may deposit energy in an individual; given in units of roentgens. Also used to refer to an individual being subjected to the presence of radiation.
external dose	The absorbed dose that is due to a radioactive source external to the individual as opposed to the absorbed dose from inhaled or ingested sources.
floodplain	Lowland or relatively flat areas that are subject to flooding. A 100-year floodplain has a one percent or greater probability of flooding in any given year.
flux, radon	The emission of radon gas from the earth or other material, usually measured in units of picocuries per square meter per second.
fugitive dust	Dust particles which are dispersed from a construction site or from trucks during hauling.
gamma dose	Radiation dose caused by gamma radiation.
groundwater	Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.
half-life	The time required for 50 percent of the quantity of a radionuclide to decay into its daughters.
hydraulic conductivity	Ratio of flow velocity to driving force for viscous flow under saturated conditions of a specified liquid in a porous medium.
hydraulic gradient	Pressure gradient; rate of change of pressure head per unit of distance of flow at a given point.
inert gas	One of the chemically unreactive gases: helium, neon, argon, krypton, xenon, and radon.
interbedded	Occurring between beds, or lying in a bed parallel to other beds of a different material.
internal dose	The absorbed dose or dose commitment resulting from inhaled or ingested radioactivity.
isotopes	Nuclides having the same number of protons in their nuclei but differing in the number of neutrons; the chemical properties of isotopes of a particular element are almost identical.

licensing	In this report, the process by which the NRC will, after the remedial actions are completed, approve the final disposition and controls over a disposal site. It will include a finding that the site does not and will not constitute a danger to the public health and safety.
maintenance, custodial (passive)	The repair of fencing, the repair or replacement of monitoring equipment, revegetation, minor additions to soil cover, and general disposal site upkeep.
micro	A prefix meaning one millionth (x 1/1,000,000 or 10^{-6}).
milli	A prefix meaning one thousandth (x 1/1000 or 10^{-3}).
Modified Mercalli (scale)	A standard scale for the evaluation of the local intensity of earthquakes based on observed phenomena such as the resulting level of damage. Not to be confused with magnitude, such as measured by the Richter scale, which is a measure of the comparative strength of earthquakes at their sources.
monitor	To observe and make measurements to provide data for evaluating the performance and characteristics of the stabilized tailings pile.
National Register of Historic Places	Established by the Historic Preservation Act of 1966. The Register is a listing of archaeological, historical, and architectural sites nominated for their local, state, or national significance by state and Federal agencies and approved by the Register staff.
nuclide	A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state.
permeability	A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.
permissible dose	That does of ionizing radiation that is considered acceptable by standards-setting bodies such as the EPA.
person-rem	Unit of population exposure obtained by summing individual dose-equivalent values for all people in the population; thus, the number of person-rems attributed to one person exposed to 100 rems is equal to that attributed to 100 persons each exposed to one rem.
physiographic province	A region of similar structure and climate that has a common geomorphic history.
pico	A prefix meaning one trillionth (1 x 1/1,000,000,000,000 or 10^{-12}).

picocurie	A measure of radioactivity defined as one trillionth curie; defined as equivalent to 0.037 disintegrations per second.
plastic limit	The water-content boundary of a sediment, e.g., a soil, between the plastic and semisolid states.
radioactivity (radioactive decay)	The property of some nuclides to spontaneously emit radiation in the form of gamma rays or charged particles.
radioisotope	A radioactive isotope of an element with which it shares almost identical chemical properties.
radionuclide	A radioactive nuclide with a specific number of neutrons and protons.
radium-226 (Ra-226)	A radioactive daughter product of uranium-238. Radium is present in all uranium-bearing ores; it has a half-life of 1620 years.
radon-222 (Rn-22)	The gaseous radioactive daughter product of radium-226; it has a half-life of 3.8 days. It is an inert gas and may escape from the material containing the radium-226.
radon-daughter product	One of several short-lived radioactive products of radon-222. All are solids.
recharge	The entry into the saturated zone of water made available at the water-table surface, together with the associated flow away from the water table within the saturated zone.
rem	A special unit of dose equivalent which expresses the effective absorbed dose calculated for all radiations on a common scale. It is defined as the product of the absorbed dose in rads and certain modifying factors, e.g., the quality factor.
Richter scale	A logarithmic scale ranging from one to 10 used to express the magnitude or total energy of an earthquake.
roentgen	A unit of exposure of ionizing electromagnetic radiation (gamma or x-ray) in air; for gamma radiation, one roentgen in air is approximately equal to one rad and one rem in tissue.
sedimentary	Descriptive term for rock formed of sediment, especially: (1) clastic rocks (e.g., conglomerate, sandstone, shale) formed of fragments of other rock transported from their sources and deposited by water or wind, and (2) rocks formed by precipitation from solution (e.g., gypsum) or from secretions of organisms (e.g., limestone).
seismic	Pertaining to an earthquake or earth vibration.

stabilization	The reduction of radioactive contamination in an area to a predetermined level by a standards-setting board such as the EPA, by encapsulating or covering the contaminated material.
surveillance	The observation of the stabilized tailings pile for purposes of visual detection of need for custodial care, evidence of intrusion, and compliance with other license and regulatory requirements.
syncline	A fold in rocks in which the strata dip inward from both sides toward the axis.
tailings, uranium-mill	The wastes remaining after most of the uranium has been extracted from uranium ore.
thorium-230 (Th-230)	A radioactive daughter product of uranium-238; it has a half-life of 80,000 years and is the parent of radium-226.
transmissivity, hydraulic	A measure of the ability of an aquifer to transmit water. The value of transmissivity is equal to the product of the hydraulic conductivity and the thickness of the aquifer.
UMTRA Project	Uranium Mill Tailings Remedial Action Project of the U.S. Department of Energy.
unconfined aquifer	An aquifer in which the water table forms the upper boundary.
upgradient	Toward a higher hydraulic gradient; the direction from which groundwater flows.
uranium-238, (U-238)	A naturally occurring radioisotope with a half-life of 4.5 billion years; it is the parent of uranium-234, thorium-230, radium-226, radon-222, and others.
vicinity property	A property in the vicinity of the Green River site that is determined by the DOE, in consultation with the NRC, to be contaminated with residual radioactive material derived from the Green River site, and which is determined by the DOE to require remedial action.
water table	The surface of a body of unconfined groundwater on which the fluid pressure in the pores of a porous medium is exactly atmospheric.
windblown	Off-pile tailings transported by wind or water erosion.
working level (WL)	A measure of radon-daughter product concentration; technically, it is any combination of short-lived radon daughter products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 130,000 MeV.

working level-month (WLM)	The exposure resulting from inhalation of air with a concentration of one WL for 170 working hours. Continuous exposure of a member of the general public to one WL for one year results in approximately 52 WLM.
zone, unsaturated	The unsaturated zone is the zone between the land surface and the uppermost saturated zone.

APPENDIX A
REGULATORY COMPLIANCE

TABLE OF CONTENTS

LIST OF FIGURES